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ABSTRACT

A large scale investigation into the development and effectiveness of a collegiate level computer-assisted instruction (CAI) course in undergraduate physics is reported. The work, which began in 1966, involved a full commitment to investigate all phases of the development, execution, revision, and cost-effectiveness of a CAI physics course from a research point of view. This volume of the study covers the topics of: 1) the statement of problems, 2) the background literature, 3) the developmental curriculum processes, 4) a description of the multimedia techniques used within the course, 5) a set of CAI physics problem exercises, and 6) the three subsequent field studies. It concludes with a presentation on cost analysis and a summary of important conclusions. Volume 2 of the study (EM009606) presents the appendices that describe in complete detail the nature of the learning material and evaluative instruments utilized. Volume 3 (EM009607) is a presentation of the CAI curriculum. (JY)

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RESEARCH AND IMPLEMENTATION OF COLLEGIATE INSTRUCTION OF PHYSICS VIA COMPUTER-ASSISTED INSTRUCTION

VOLUME I

November 15, 1968

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PREFACE

This report represents a long and diligent effort on the part of many individuals at Florida State University to investigate in a substantial manner the developmental and effectiveness factors in a collegiate level Computer-Assisted Instruction course in undergraduate physics. The challenge of creating a course for a computer-based presentation, especially at the beginning of the project in 1966, were considerable. The project was arduous both in terms of its size and challenge because of the full commitment to investigate all phases of the development, execution, revision and cost effectiveness of the CAI Physics Course from a research point of view. We trust that this report sufficiently describes the findings and proves useful to educators and researchers in terms of understanding the nature of CAI curriculum development as well as some possible implications as to its positive pay-off for collegiate instructions.

Past experience has indicated that a wide variety of scientists and educators will be interested in this report. Consequently, we have organized the final report into three parts in order to facilitate better dissemination. Volume I consists of the main body of the report. This covers the topics of 1) the statement of the problem, 2) the background literature, 3) the developmental curriculum processes, 4) a description of the multi-media techniques used within the course, 5) a set of CAI physics problem exercises, and, then, 6) the three subsequent field studies. Volume I is concluded with a presentation on cost analysis and a statement of what we consider the important conclusions. Volume II presents the appendices that describe in complete detail the nature of the learning materials and evaluative instruments utilized. This covers such topics as the course objectives, the data management system utilized for course monitoring and revision, booklet utilized by the students, presentation of audio lectures, homework problems, descriptions of films plus personality and attitude instruments. Volume III is a presentation of the CAI curriculum. This is broken up into two parts, that is, the 1500 CAI course and the problem sets presented via the 1440 computer. We trust this organization will prove useful to the different types of readers who would not want to be burdened with extra material unless they have an express purpose for it.

We wish to thank USOE and personnel in the Bureau of Research who have patiently advised and critiqued this project. We especially wish to thank Dr. Louis Bright for helping in the initiation of the project, plus Dr. Howard Hjelm, Dr. Andrew Molnar, Dr. William Adrian, and Dr. Howard Figler for their continuing interest and advice.

Here at Florida State University we wish to thank Dr. Steven Edwards, Dr. Gunter Schwarz, Dr. William Nelson, Dr. Neil Fletcher, and Dr. Robert Kromhout of the Department of Physics. Their conceptional advice, editorial assistance, and continuing interest were invaluable to the execution of this research project. We wish to thank Mrs. Ora Kromhout, Albert Griner, Joseph Betts, Marjorie Nadler, and Robert Hogan who authored the CAI materials. We wish to thank Mrs. Betty Wright, Mrs. Charlotte Crawford, and Mrs. Sharon Papay for their diligent efforts in coding and debugging the CAI course material. In turn, we wish to thank Mr. Beverly Davenport, Mr. Eugene Wester, and Mr. Wayne Lee for their efforts in developing the computer programs, especially in the area of data analysis, that allowed for the course revision. We wish also to thank our numerous, invaluable graduate students who contributed instrumentally in the development of the project. These were Kenneth Majer, Harold O'Neil, Leroy Rivers, Paul Gallagher, James Papay, and William Harvey. And lastly, the help of our secretaries in both the preparation and editing of this report was invaluable. We, therefore, wish to thank Louise Crowell, Dorothy Carr, Harvey Varner, Mary Calhoun and Ann Welton.

We trust that the findings from this report will prove useful and represents a sound investment on the part of the Bureau of Research of the U. S. Office of Education.

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I

INTRODUCTION

Higher education today faces the greatest crises in its history as it seems to be increasingly unable to meet the demands placed upon it by society. Many reasons for this can be readily identified. First, our population has increased markedly and, by implication, so has the number of youths to be educated, especially in the more technical areas. Concomitantly, scientific knowledge is increasing at an exponential rate such that the complexity and absolute amount of the information that must be taught as common to all men is vastly increasing. Technological changes are so swift and frequent that liberal and professional education is now being regarded as a life-long activity. The institutions and procedures for extending collegiate level instruction imply that there is a sharp imbalance between the supply and demand of competent available staff. Moreover, our entering freshmen are both brighter and more prone to critical thought. As a consequence, the demands on higher education are greater today than ever before. Thus, several facets of the crises in higher education include the vast increase in students, the great expansion in knowledge, the broader commitment to collegiate and post-collegiate education, and the higher expectations of our student and adult populations.

The study reported here was a large scale investigation into the role and potential efficacy of computer-assisted instruction (CAI) as a significant solution for resolving some of these highly complex problems now facing higher education.

The major purposes of this research project were to prepare and perfect a CAI course in introductory collegiate physics and to compare it with the conventional lecture/demonstration course at Florida State University. The comparison of the two modes of instruction consisted of a) learning effectiveness of each, b) specific learning difficulties in physics experienced by college students, c) students' reactions to the two modes of presentation, d) relative costs and procedural requirements for implementing the two modes of instruction, and e) the relationship between variables of learning and attitudes in CAI. As a corollary purpose, the investigation of a new research and development model in implementing computer-based courses was pursued. Thus the primary goal was to develop a body of factual knowledge based on controlled observation, experimentation, and development, that provides the answers for college educators who have been considering the role of technology in their educational institutions.

This report has been organized in a chronological fashion. First, a review of the background literature pertinent to the areas of physics education, computer-assisted instruction, and technologically based multi-media instruction are presented in section II. This is followed by a description of the "systems approach" model utilized by the project team in developing and implementing the courses. Within this third section there is a comparison between the advantages and disadvantages of a team approach utilized within the project as opposed to the independent professorial approach more commonly found in educational development endeavors.

In section IV, there is a description of the corpus of the multi-media computer-based physics course. This is followed in section V by a discussion of the CAI physics problem exercises that were utilized both to implement certain curriculum sections, as well as to establish base-line data for the evaluation of the fully automated course. The next three sections consist of descriptions of the field studies which were conducted in the fall of 1967, the spring of 1968, and the fall of 1968. In order to evaluate the cost/effectiveness of the course, section IX presents an economic analysis of the learning outcomes. Section X provides a summary and a concluding statement. In order to provide complete documentation, there are extensive appendices which provide a full description of the course, plus all evaluative instruments utilized in the implementation and evaluation of project activities.

II

BACKGROUND LITERATURE

This review is expressly concerned with four instructional research topics: 1) the general instructional effectiveness of CAI, 2) the general instructional effectiveness of multi-media instruction, 3) the correlational analysis of student characteristics and their relationship to success in physics, and 4) the interactive nature of the relationship between personality variables and scholastic achievement. These topics are either directly or indirectly related to the major questions being examined in this report.

A. Instructional Effectiveness of Computer-Assisted Instruction

Effectiveness of CAI has been repeatedly demonstrated at the FSU and other CAI centers. Franceschi and Hansen (1967) adapted materials about commercial television program-rating to both instructional television (ITV) and to an IBM 1440 CAI presentation which utilized teletypewriter terminals. Evaluation of performance differences yielded significant positive results in favor of CAI. They conclude that, in general, CAI proved to be a more effective learning device than ITV or a combination of ITV and CAI.

Hansen and Dick (1967) report favorable findings of a developmental seventh, eighth, and ninth grade CAI science curriculum study as follows: ". . . evidence that the students from whom the data is derived perform at least as well on achievement tests as other students who receive comparable material in a conventional classroom." Snyder (1967) in a later report on the same Intermediate Science Curriculum Study (ISCS), describes the sequential evaluative and record-keeping techniques of the CAI system as the initial innovations which have made the formative evaluation of ISCS successful. The developers of the ISCS program are concerned with maximizing the achievement of each of the individual students receiving instruction. They believe that CAI provides an excellent opportunity for examining individual differences in the context of an ongoing science course. Further, Snyder states that using CAI to collect and analyze individual records provides the kind of formative evaluation data which cannot be readily obtained in the large scale classroom-type field study.

Success with individualized instruction with CAI has also been reported by Proctor (1967). The subject matter taught in this experiment was selected from an education course pertaining to curriculum development in elementary and secondary schools. Comparative analyses between a CAI program taught via the IBM 1500 system and a lecture-discussion group taught by Proctor yielded results favoring CAI on both the posttest and a retention test.

Stanford University has successfully used CAI for individualizing instruction in a variety of programs. Suppes has successfully taught Russian to college level students (1968); arithmetic to elementary school children (1968); and, reading to primary level school children (Atkinson, 1968). His Stanford and Brentwood projects have been considered two of the major efforts to implement feasible CAI operations.

Hickey (1968) in his recent survey of the CAI literature, summarizes the state of the art. He provides an exhaustive review of the historic development of CAI, applications of CAI, major centers and their activities, programming languages and specific research projects. The survey leaves little question that CAI is a viable research, curriculum development, and instructional tool.

B. Instructional Effectiveness of Multi-Media Instruction

Criterion-referenced testing and normative comparisons are both acceptable ways of evaluating specific media. Media studies have noticeably chosen the latter. One suspects that this choice derives from the ease of interpreting normative data. It is a straightforward justification to use a certain medium if research results indicate that it is "equal to" or "better than" an alternate method. Since both superior instructional effectiveness and a lessening of the teacher's instructional burden are desirable goals, studies reporting equal or better instruction with media as compared with traditional methods have been considered positive results that point directly toward a course of action.

1. Motion Picture Presentation. Numerous studies have indicated that university, senior and junior high school, and elementary school students can be taught effectively by motion pictures. McElroy (1958) experimentally determined the effect of motion picture instruction for the improvement of speaking techniques in beginning university public speaking classes. He found no significant differences between films and classroom procedures. At the junior high school level, similar results have been reported for both eighth and ninth grade students receiving general science instruction through films (Champa, 1958; VanderMeer, 1950; and Huffman, 1958). Studies with high school chemistry and physics students yielded comparative data which show no significant differences between classroom and motion picture presentation (Popham and Sadnavitch, 1960; Sadnavitch and Popham, 1961). Stuit, et al. (1956) used a college population to show film effectiveness equal to that of classroom presentation for classes in American government and comparative foreign government. College physics demonstrations, similar to the concept films used in the present CAI/Media course, were shown to be effective as early as 1951 (Tendam). Allen (1960) cites several studies that indicate motion pictures are at least as effective as conventional instruction in teaching factual information and perceptual motor skills.

Some studies report findings which tend to support the contention that motion pictures actually produce better results than traditional modes. Cobbs (1941), with elementary school natural science, Murphy

(1961), with a seventh-grade lesson on light, and Nelson (1952), with a high school chemistry lesson on sulphur, all showed significantly better learning by motion picture presentations as compared to traditional classroom methods.

Finally, Greenhill (1964), in his introduction to a volume of abstracts of research on instructional TV and films by MacLennan and Reid (1964), comments that in general no significant differences were found in the bulk of studies comparing filmed courses with direct instruction in such subject matter areas as college level psychology and communication skills, high school chemistry, physics, history, and industrial arts.

These studies provide results which indicate that motion picture presentations are at least as effective as lectures on comparable materials, and sometimes appear to be a more effective mode of instruction.

2. Tape Recording Procedures. Because of the relatively small number of available comparative studies of radio and tape recordings, there is little evidence on the instructional capability of these media. However, Allen (1960) cites two studies (Barr, et al., 1942; Cook and Namzek, 1939) which show no difference between radio and classroom presentations, and two studies (Wiles, 1940; Miles, 1940) which found superior learning by radio. Based on these studies, Allen feels that radio and recordings have been found at least as effective as conventional instruction. Popham (1961) offers a concurring point of view. He taught a graduate level course in educational research by a series of tape recorded lectures combined with brief instructor-led discussions. When the experimental group was compared with a group taught by standard lecture and discussion methods, no significant differences were found. In a later study, (1962), Popham replicated his experiment using as subject matter a college course on Principles of Secondary Education. His results again failed to show significant differences between the experimental tape recording group and the lecture control group.

Although the literature here is not as prevalent as with other types of media, the evidence appears conclusive that audio-instructional presentations can be as effective as lecture methods. This provides a rationale for using recording tapes when they can provide individualization in terms of presentation to particular students when each student is ready for the presentation.

3. Programmed Instruction. Much of the research effort in PI has been concerned with basic studies of innovation designed to increase this medium's effectiveness. Although it is beyond the purpose of this review to enumerate these basic developmental-technique studies, it is worth noting the types of variables which generally are embedded in the programs in the comparative effectiveness studies reviewed below. Campeau (1967) lists these variables as follows:

knowledge of correct response, prompting versus confirmation, response mode, hardware versus software, pacing, and step size.

Comparative effectiveness studies show strong support for the instructional effectiveness of programmed instruction. For example, Schramm (1964) found that of 36 studies comparing programs with conventional instruction, one-half (18) showed no significant differences and 17 showed a significant performance difference favoring programmed groups. Briggs and Angell (1964) cited 19 studies--5 in the area of science and 14 in mathematics--in which the effectiveness of programmed instruction was compared with conventional teaching methods and noted that non-significant differences were reported more often than were significant differences favoring PI. Strong (1964) cites studies comparing programmed instruction with conventional instruction in a college statistics course (Smith, 1962) and a unit on the use of the library (Wendt and Butts, 1962); no significant differences were found in these two studies. Porter (1959) used a teaching machine to present programmed spelling to second-grade and sixth-grade children. Control groups were taught by standard lessons in textbooks which paralleled the programs closely. Significant differences in achievement on standardized tests favored the program groups at both grade levels. Evans, Glaser, and Homme (1960) used programmed materials to teach part of a course on music fundamentals. The control group was taught by conventional methods. On a test of music notation, the program group surpassed the control group by a significant margin.

Roe (1962) compared the performance of groups who learned elementary probability either from programmed textbooks, teaching machines, programmed lectures, or conventional lectures-and-textbooks. Students who used the programmed material in any form performed significantly better than those using the conventional methods; however, there were no differences in learning achievement among the various program groups. Ripple (1963) taught university students principles of programming by one of four instructional methods: (a) programmed instruction which supplied feedback about written responses, (b) textbook (this was the program reproduced in textbook format--no blanks to be filled in), (c) conventional lecture (based on reading the programmed material to the students, or (d) programmed instruction which did not supply feedback. The two program groups learned significantly more than the textbook and lecture groups, with no significant difference between the program treatments. Finally, Moldstad (1964) cites a study by Stewart in which college students from two universities were taught factual information by one of three methods: programmed instruction, a motion picture, or a combination of the two media. On a test given immediately after learning, the program-only and program-film groups did significantly better than the film-only group.

This sample of studies from the programmed instruction literature provides more than adequate rationale that programmed instruction often provides remarkable learner achievement.

C. Student Characteristics and Achievement in Physics

There have been a number of studies which investigated the relationship of student characteristics and achievement in physics. Some studies have focused on high school physics, others on college physics, and still others on the transition between the two. The results of these studies have been relatively inconclusive at best; no concrete guidelines have been established which have led to the facilitation of physics instruction. Although these studies have been largely based on individual instructors and their unique instructional methodology, the results reported below provided useful and insightful suggestions for the current area of inquiry.

Dunlap (1966) investigated the relationship between knowledge of elementary algebra and achievement in high school physics. A sample of students in Tucson, Arizona, were given a standardized achievement test in algebra at the beginning of their school year. These scores were found to positively correlate with the final grades in the physics course ($r = .50$, $p < .01$). Dunlap hypothesized that perhaps the high correlation was due to the dependence of the two courses on reasoning skills. Additionally, it was proposed that the fundamental algebra was required to solve physics problems.

Renner et al. (1965) was interested in college professors' opinions about the necessity of high school physics for success in the college course. He found that most professors felt high school physics was necessary for success in college physics; a few, however, could report little difference between the two groups. Renner concluded that the types of high school and college courses vary to such a high degree that no general trend should be expected. Kruglak (1959) also studied the relationship between performance in high school and college physics. He found a difference in grades in introductory physics at Western Michigan University between those students with and without high school physics. Those with high school physics received a much higher percentage of A and B grades than those without high school physics. The students without high school physics also received a much higher percentage of D and F grades.

Woodward (1963) attempted to predict success in college physics using various student performance indices. For this study he correlated three types of factors with college physics grades of students at Oklahoma State University. The characteristics investigated were high school performance, college performance, and scores on various standardized tests. The high school grades included science, mathematics, and English, as well as average high school achievement. College grades in mathematics and chemistry, and college grade point average were also utilized. The test battery consisted of the Cooperative Algebra Test, Pre-Engineering Ability Test, ACE Psychological Examination, and Kuder Preference Record. The results indicated that overall college grade point average was the best predictor of success in college physics. The Pre-Engineering Ability Test and Cooperative Algebra Test had lower correlations with the criterion, but were also significant. The best predictor of college physics success in terms of high school performance was high school physics achievement.

Bolte (1966) used twelve background variables to predict success in college physics of students at the State University of Iowa. Only five of these variables were found to be significant at the 5% level of confidence. They were high school physics, high school grade point average, freshman college mathematics, college calculus, and college chemistry. High school grade point average was by far the best predictor.

Hassan (1966) used North Carolina State University students to perform a study similar to that of Bolte's. The students involved, however, were limited to engineering and physics majors enrolled in an introductory calculus-oriented physics course. He found that three variables were significant ($p < .05$) in predicting success in college physics. They were cumulative college grade point average, grade in high school physics, and score on the mathematics part of the Scholastic Aptitude Test.

Finger et al. (1965) performed a study at Brown University which attempted to isolate differences in performance by students who 1) had no high school physics, 2) had PSSC physics, or 3) had a conventional physics course. Again, grades in college physics were used as the criterion measure. The results favored the PSSC group, but the difference was not significant.

Hipsher (1961) conducted a related study to the one above at Will Rogers High School in Tulsa, Oklahoma. His purpose was to compare the effectiveness of a PSSC program to that of the traditional high school physics curriculum when form two of the Cooperative Physics Test was given at the completion of the course. The same teacher taught each course in successive years. The variables of scholastic aptitude, physical science aptitude, prior achievement in natural science, and what Hipsher defined as socio-economic "stations" were statistically controlled through the use of covariance analysis. He found that the students in the traditional class performed significantly better ($p < .01$) on the Cooperative Test. Hipsher acknowledges that the test per se might have been biased towards the traditional curriculum. He points out that most colleges still follow the traditional physics curriculum, so the results may give an indication of probable success in college physics.

In the studies reviewed above, many types of independent variables were used. These variables included algebra achievement, high school or no high school physics, high school background and grades, college background and grades, and results on standardized aptitude tests. The dependent variable was final grade for the college physics course in all the studies cited. The researchers used expert judgment, correlational matrices, analysis of variance, and multiple regression techniques in their studies. Perhaps the best generalization that can be drawn from the findings is that high school and college grade point average, and mathematical aptitude and achievement were, in general, found to be the best predictors of the final grade in college physics.

D. Individual Differences and Technology

The above review has established that various media including PI and CAI are effective modes of instruction. The researchable questions now being pursued are becoming more specific within this realm of educational technology. This trend is reflected in the research efforts which have utilized programming capabilities and the logistical advantages of media in an attempt to successfully adapt technology to the individual differences of students. Suppes (1964), for example, notes computer controlled accommodation to the wide varieties in learner rate in drill material. Gropper and Kress (1965) concur: "Some learners need to be speeded up and some need to be slowed down to improve the effectiveness and efficiency of learning. If a learner-determined rate is too fast, more errors occur, primarily because of low IQ. Many high IQ learners proceed slowly and inefficiently, while many low IQ learners go fast and inefficiently."

Experimentally testing different instructional strategies has been a popular method to try to find the best way to account for learning differences. Rodgers (1967) divided CAI strategies into five categories: drill, tutorial, conversational, simulated environments, and simulated decision-making. From samples of economics programs representative of these categories, Rodgers concludes that since sophisticated branching would incorporate options as conceived by the learner as well as by the teacher it is the appropriate way to accommodate for individual differences. Like Rodgers, Melaragno (1966) found that branching and prediction adaptations to individual differences are more effective than linear techniques.

An elaboration of intrinsic branching programs was developed and described by Hellerstein, et al. (1967). It is a general teaching paradigm based on the Socratic dialogue with supplemental branching strategies. Different paths in the student-computer dialogue are possible, and the one that unfolds is contingent upon the student responses--not solely upon the immediately preceding choice, but also upon those made over the entire program, including responses made on pretests. Hellerstein gives examples of five instructional strategies and flow charts of five student response paths.

The branching decision-making model is a sophisticated extension of adapting the system to the individual. This model (as exemplified by Shuford, 1965) not only causes the computer to match the student's response to a multiple-choice frame with a defined correct response, but also to record the degree of certainty the student indicates for all of the alternatives offered by the program at the choice point, both right and wrong. Unlike the conventional multiple-forced choice program, the student makes no "errors." He progresses through levels of certainty and the computer always acts in the direction of raising his certainty (Shuford, 1965; Shuford and Massingill, 1966; Baker, 1965).

Much of the effort which has been extended toward accommodating individual differences has been to develop systems of instruction which are adaptive to the needs of the individual. Briggs (1968) however, claims that one cannot know whether any particular media is the proper one to adapt to individual needs before one knows what the individual needs are. Briggs feels, for example, that most decisions strategies for branching (individualization) are inadequate since they do not evaluate the student's complete competence well enough. Adherence to Briggs' principles of effective individual adaptations for maximum student performance supports the need for the research work of investigators who seek to find interactions between individual differences variables and educational technologies.

Doty and Doty (1964) reported that achievement through programmed instruction appeared to be related to personality characteristics. They reported a nonsignificant correlation between general achievement and learning from their program. Also, they reported a high positive correlation (.71 for girls, but .40 for both sexes) between grade point average and attitude toward PI, but no significant correlation between achievement and attitude.

Woodruff, Faltz, and Wagner (1966) correlated subscores on two personality tests (EPPS and Gordon Personal Inventory) with the number of correct responses on programmed instruction frames. Significantly correlated with performance were achievement motivation ($r = .53$), cautiousness ($r = .50$), original thinking ($r = .74$), and personal relations ($r = .81$). The correlation of IQ with frames correct was .75.

Other relationships between personality variables and PI and CAI performance have been documented in recent years. Lubin (1965) reported that college students in introductory psychology who scored low on autonomy performed better in PI than those with high autonomy. (Autonomy from Edwards Personal Preference Schedule was defined as liking to work alone without the teacher.) Kight and Sassenrath (1966) reported that high achievement-motivated students performed better in a PI sequence on three separate criteria than did students with low-achievement motivation. The criteria were: the time to complete the program, the number of errors, and short-term retention scores.

Relationships between performance and variables which are not in the strict sense personality variables also have been found. Cooper and Gaeth (1967) have shown the significance of age as a factor which can dictate whether pictorial or auditory stimuli should be used as the mode of instructional presentation. Snow, Tiffen, and Siebert

(1965) examined the effects of attitude on performance and showed that a negative attitude toward films can have a significantly detrimental effect on performance. James (1962) found similar results when he examined the effects due to preferences for specific media.

All of the studies mentioned tend to support the general hypothesis that indeed there are personality, attitude, and aptitude characteristics which have an effect on an individual's performance in a given educational setting.

1. Anxiety and Learning. Many review articles indicate that anxiety interferes with the learning process (Spielberger, 1966b; Sarason, 1960). In many cases, the anxious student's level of achievement is not commensurate with his intellectual aptitude, and his confidence in his own abilities is therefore seriously undermined.

The literature concerning anxiety and its effects on performance with PI and CAI will be delineated. Previous research into the effects of anxiety suggest that high anxious students will make more errors than low anxious students on difficult PI or CAI materials, while high anxious students will do as well or better than low anxious students on easier PI or CAI materials.

Riley and Riple (1967) investigated the importance of the contribution of anxiety and other extrinsic individual difference variables to achievement in PI. A weighted Test Anxiety Scale for Children (Sarason, Davidson, Lighthale, Waite, and Ruebush, 1960) was used as an anxiety measurement. A lengthily constructed response linear program was given to 165 sixth graders. The results indicated a correlation of -.53 between the anxiety weighted score with a difficult posttest. Regression analysis of the same data yielded a significant beta for the anxiety scale, indicating that anxiety, independently of other variables, was accounting for about 6% of the variance.

Kight and Sassenrath (1966) hypothesized that high test anxious students would perform better than low anxious students in a PI situation. Their measure of anxiety was a Test Anxiety Questionnaire (Mandler and Sarason, 1962). The low difficulty learning materials consisted of six hours of PI. Results for 139 college students indicated that the high anxious students worked faster and made fewer errors than the low anxious students, but failed to exhibit higher retention scores. The authors postulated, as a result of these findings that more highly motivated students would benefit more from knowledge of results than less well motivated students would. In addition, given the ease of the learning materials, it would have been predicted from drive theory that the high anxious students would have performed better.

A study by Campeau (1968) provides additional data to test Kight and Sassenrath's (1966) interpretation of their results. Campeau investigated the effects of test anxiety on the presence or absence of feedback in a programmed learning situation using the Test Anxiety

Scale for Children (Sarason, et al., 1960) as the anxiety measure. The learning materials were presented to fifth grade Ss in a three-hour PI format. Both a posttest and a delayed retention test were administered. Results indicated that high anxious girls in a feedback condition had better immediate retention than the high anxious girls in the no-feedback condition. The delayed retention measure indicated that low anxious girls performed better than high anxious girls under no-feedback conditions. There were no significant differences among males. Campeau hypothesized that when feedback was omitted, the test-like aspects of the program would be accentuated, leading to greater anxiety in the high test anxious students.

2. Learner-Treatment Interaction. The adaptation of media to individual differences has placed emphasis on the manipulation of media to adjust for these individual differences in human ability. According to Briggs (1968a), this is what Gagné would describe as "adapting media to the learner." However, given that a proven system for media instruction has been developed, a reasonable strategy to consider is one of assigning persons to the media. This is especially true when the demand to use the media system is greater than the system's capability to provide the service, and expansion of the system is economically unfeasible. Lumsdaine and May (1965) express their attitude toward this strategy in this manner: "Just as one medium cannot be shown best across the board or even for one subject matter area, so also one cannot show that one medium is best for one type of student." They argue that the proper use of media will be best determined by the comparison of learners with particular characteristics to learners having other characteristics when particular media are programmed in well defined ways. Similarly, Hartley (1966) feels that effective learning will result from the utilization of data from attitude questionnaires, studies of novelty and boredom, studies of individual differences, studies of groups as opposed to individual instruction, and, finally, the influence of administrative necessities, to judiciously match people to programming techniques.

Particularly relevant at this point to the general discussion of individual differences are the questions which have been generated by Ingersol (1967) and Bush, et al. (1965): Ingersol asks, "What kind of individual prefers independent learning to more traditional classroom learning?" Bush, et al., asks, "What interacts between individual differences and modes of instruction?"

Snow (1969) reports a study which follows this line of questioning in the area of primary grade reading research. He reports interactions of ability and program method which lead to the conclusion that the phonic method of instruction appears more appropriate for low ability subjects, while higher ability subjects seem to learn better with the look-say method. Snow (1969) also reports interactive results which provide evidence that prospective teachers differentially perform on hypothesis generation training and cue attendance training contingent upon GRE verbal performance achievement. He found that hypothesis generation training produces more information search behavior among subjects with GRE-V scores above 550, while production is higher after cue attendance training for subjects scoring below 550 on the GRE-V.

Aptitude-Treatment interactions are also reported by Kropp, et al. (1967). They found interactions to exist in a variety of subject matter contents including mathematics learning, vocabulary learning, reading and chemistry achievement. Kropp, et al., feel that the implication of their results is that it is reasonable to think that achievement of students can be enhanced by assigning them to instructional materials known to be optimally related to their ability patterns.

E. Summary

Numerous research findings which are related to the current study in CAI physics have been reviewed in this section. In general, these results indicated that:

1) High school and college grade point average, and mathematical aptitude and achievement have been found to be the best predictors of success in collegiate physics.

2) CAI, although still in the experimental and early implementation stages, has been shown to be an effective instructional device in a number of areas.

3) Many studies have shown no significant differences in students' performance in classes taught via (a) films, (b) television, and (c) tape recordings as compared to conventional instruction.

4) Most studies indicate the students perform at least as well, if not significantly better, with programmed instruction as compared to conventional instruction.

5) Numerous studies document that personality, attitude and aptitude characteristics have an effect on the performance of an individual in a particular learning context.

6) Certain research studies indicate a definite trait by treatment interaction effect. Investigation with both ability and personality variables have demonstrated this effect.

III

CAI CURRICULUM DEVELOPMENT PROCESSES

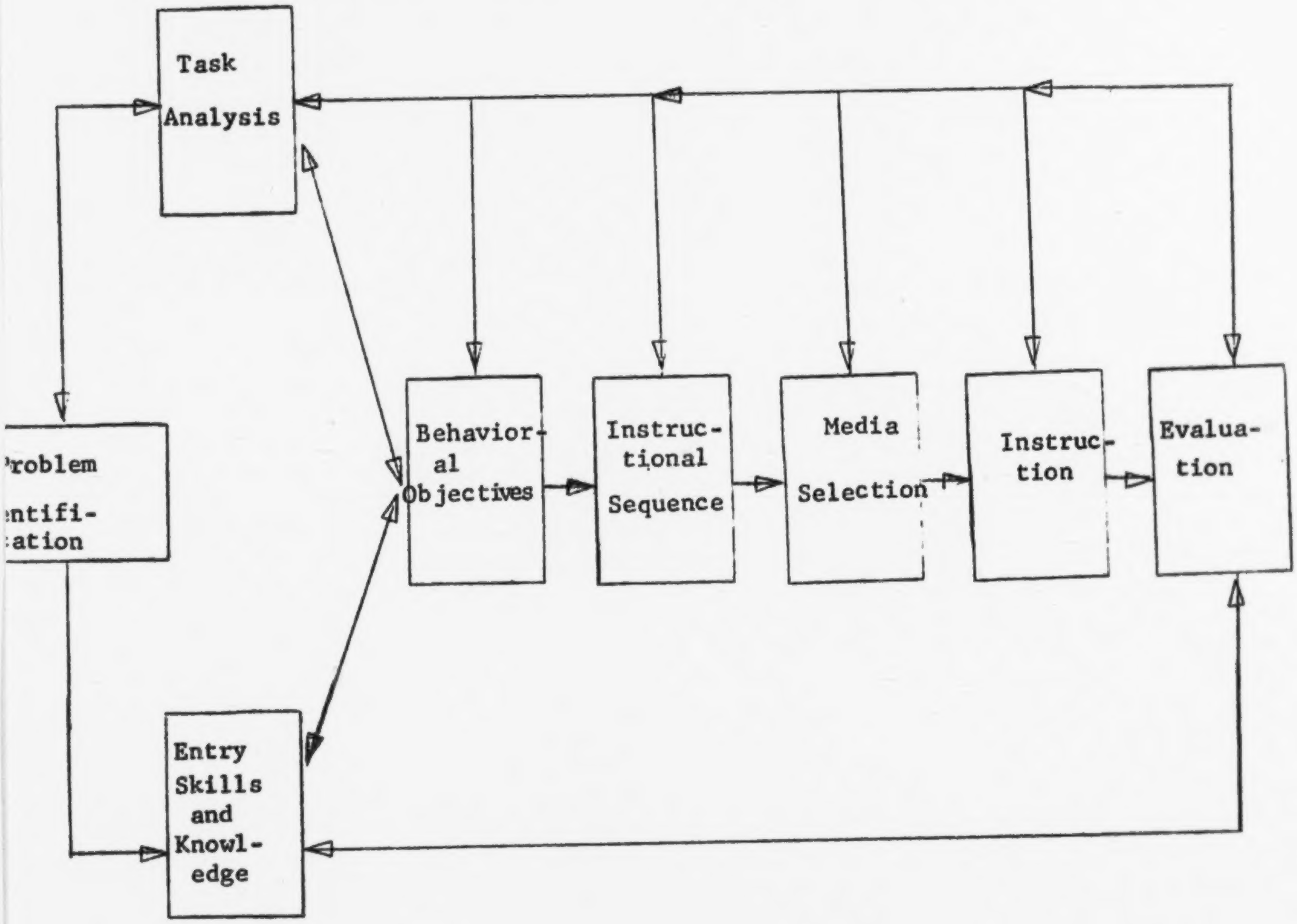
A. Introduction

This section will describe the curriculum development techniques and procedures, both explored and discovered during the implementation of the multi-media computer-based collegiate physics project. The primary outcome of this implementation process was a formal conceptual model referred to as the "Systems Approach" to CAI curriculum development. As will be reviewed for specific R and D activities encompassed within this project, the essential components of the systems approach are: 1) problem identification, 2) task analysis, 3) student entry behaviors, 4) behavioral objectives, 5) instructional strategy, 6) media assignment, 7) field test, 8) revision cycle, and 9) management techniques. As a consequence of the utilization of the systems model in the development of the physics course, ten significant professional roles in multi-media CAI curriculum development have been identified. The salient characteristics of each of these roles will be described. In turn, the development of the computer data analysis and management system required to support the curriculum revision cycles will be reported. As a comparison to the merits of the systems approach, we will discuss individual, professorially sponsored CAI curriculum efforts. The section concludes with a set of summary factors which are considered consequential in the development of multi-media CAI materials.

B. Systems Model for CAI Curriculum Development

The systems approach has evolved as a set of ideal analysis and implementation procedures that can be followed in order to develop effective learning materials which in turn maximize the conceptual development of the students. The essential features of the systems model are schematically presented in Figure 1 (Dick, 1969). The first step in the process is the exploration and description of the instructional problems plus associated context constraints of the instructional setting. Concurrently, a task analysis of the conceptual requirements, as well as the behavioral processes, should be performed. A thorough assessment of the entry skills and prior knowledge of the student population for which the course is intended is also required. These sub-analyses then culminate in the course behavioral objectives which form a description of the criterion performances which are desired as outcomes for the student. In turn, the behavioral objectives are sequenced and structured into instructional strategies for given segments within the course. As a consequence, appropriate selection of media and instructional contexts provides the implementation prior to the first field test. The empirical results obtained in the field test provide the basis for evaluation and subsequent revision cycles.

Systems Development Model



Task Analysis
Problem
ntifi-
ation
Behavioral Objectives
Instructional Sequence
Media Selection
Instruction
Evaluation
Entry Skills and Knowledge

Figure 1

While this is an extremely brief presentation, each of the system's components will be described in more detail below. The adaptation and utilization of the model by the physics project staff in implementing and evaluating the multi-media computer-based collegiate physics course will be emphasized.

1. Problem Identification. In the process of describing the existing instructional problems within the physics course, P 107, it was found useful to employ a number of techniques by which to reveal specific problems upon which the CAI interaction could focus. If conceptual learning problems can be identified in terms of behavioral phenomena such as prior test scores or responses on homework assignments, a CAI project will be much further ahead in its formularization of appropriate behavioral objectives.

Four techniques were utilized to identify problem areas within the physics course. First, a thorough literature search of the physics education area provided information about the needs of students for prerequisite quantitative abilities, for high order abstracting and concept formation abilities, and for sophisticated problem-solving skills. In the last analysis, it was apparent that one learns physics to the degree that one can solve physics problems. This primary behavioral focus on problem solving for physics courses should not be minimized.

The second technique involved a number of conferences with Dr. Steve Edwards, Dr. Guenter Schwarz (members of the FSU physics faculty) and the project staff in order to gain case study information about learning problems revealed during class discussion periods as well as faculty office hours. These conferences pointed up the need for good conceptual development and associated problem-solving skills plus the deficiency of student motivation for certain aspects of the course. These motivational factors seem to determine class attendance, work effort, and general intellectual commitment.

In terms of the third technique, all of the prior test results over the previous three-year period provided a clear indication that the later portions of the course, namely electromagnetic phenomena and atomic physics, provided the greatest difficulty for the students in terms of items failed on final examinations.

The fourth technique for identifying difficult concept areas incorporated a set of CAI instructional problems which were presented on four different occasions to samples of students enrolled in the conventional physics course (these physics CAI problem exercises are described more thoroughly in section V). The performance of the students on these CAI instructional problems provided performance data upon which all future comparisons for revision and improvement purposes were based. The availability of baseline data is an extremely useful technique and should not be minimized. Lastly, prior homework assignments and related student performance were analyzed to again identify problems.

All of these efforts clearly indicated that throughout the course there were specific learning or conceptual problems that the overall performance, as is portrayed in the report on the physics CAI practice problem sets, indicated a gradual decline in performance and understanding by the students as they proceeded through the course.

2. Task Analysis. A task analysis of the curriculum concepts to be taught to the students provides an overall structure of the course content in a manner that delineates the relationship among topics in both sequential and hierarchical fashion. In terms of P107 physics, the integrating conception of particle and wave phenomena provides a recurrent and increasingly complex set of theoretical propositions as the student moves through the topics on measurement, optics, mechanics, electromagnetism, and modern physics. This relatively stable conceptual structure has evolved over a long period of time and is easily inferred by a review of existing textbooks.

For the purposes of the project, the task analysis of the content was performed in two ways. First, a video recording was made of the twenty-nine conventional classroom lectures and demonstrations. These video tapes provided an opportunity to study both the detailed presentations of concepts, but more importantly to identify the language and representatives utilized in the conventional setting. Parenthetically, it is highly recommended that video recordings of a professor who is highly successful in conventional teaching provides many important insights into the pedagogical techniques and language appropriate for instruction in a given course area. Moreover, the video recordings allow one to identify the characteristics of concept presentations which will be of value when consideration is given to media assignment. And, lastly, it provides an invaluable tool by which the professor can compare and reconsider the sequencing of portions of the course.

As a second task analysis technique, four currently popular physics textbooks were analyzed. Interestingly enough, the topic sequence in all of these textbooks was exactly equivalent; that is, the authors employed the concepts of particle and wave phenomena in order to integrate the topics within the introductory physics course. As an additional benefit, the analysis of the homework problems offered at the end of each chapter indicated many of the behavioral requirements currently considered important in introductory physics.

Thus, a clear representation was obtained for the twenty-nine lessons that are described in section IV.

3. Entry Behaviors. An empirical assessment of the skills and performance level of the student population as they enter a course is an absolute prerequisite for the preparation of optimal learning materials. These performance levels are commonly referred to as entry behaviors. Entry behaviors represent a characterization of the heterogeneity of both cognitive and affective processes and prior knowledge levels on the part of the students. Obviously, as gaps or deficiencies

are revealed, these impinge directly on the conceptual attainment as represented in the task analysis. In essence, entry behavior should indicate both the aptitudes and abilities of the students at the beginning of the course and the appropriate entry points into the conceptual flow identified within the tasks analysis of the course.

The entry behaviors of the students were assessed in terms of scores on the Florida Collegiate Entrance Examination, performance on midterm and final examinations in the conventional physics course and most importantly the performance on the CAI problem sets. These CAI problem sets were a fair representation of each of the sub-concepts presented in the conventional setting. The students typically came to the CAI Center prior to each examination for one to two hours of instructional interaction. As will be described in section V, each item posed a physics problem; if the student could not answer it, help was provided until a successful answer was emitted. The preparation of this type of CAI complementary problem set is highly recommended in order to specifically identify the performance level of students both prior to and during a conventional course presentation.

Problem sets have great merit in that they save a great deal of time and energy in terms of preparing desired remedial materials and delimiting professors' and authors' intuitions about potential learning problems. The area of CAI curriculum development has been fraught with extensive remedial material preparation which is rarely used by any of the targeted students. It was discovered that utilizing the CAI homework problem results saved considerable time and focused the preparation of learning materials specifically on difficulties demonstrated by concurrently enrolled students. Thus empirical techniques provide an efficient approach to specifying student entry behaviors.

4. Behavioral Objectives. Information from the course analysis, task analysis, and entry performance levels was utilized in formulating the behavioral objectives of the automated P107 physics course. Since a direct comparison with the conventional course was desired, the concepts and related behavioral objectives were arbitrarily divided into twenty-nine segments referred to as lessons. These closely parallel the presentations in the conventional lecture-demonstration course. The behavioral objectives were treated as hypothesized propositions which could be and ought to be achieved by the students given an effective instructional treatment.

For each lesson the behavioral objectives were broken down in terms of prerequisite skills and concepts plus the behavioral objectives for that given instructional segment. A descriptive example of this can be found in section IV, and all of the objectives are listed in Appendix A. It was observed in the process of stating the behavioral objectives that the availability of prior test items as well as the video recordings of the conventional class presentations proved an invaluable data source from which to formulate precise performance related statements. These precise behavioral objectives assist one in the next step, namely, forming instructional strategies. Thus, the accumulation of prior skills and concepts lead one to a workable set of behavioral objectives.

5. Instructional Strategies. Since the conceptual structure of the collegiate physics course did not pose major sequencing problems because of the constancies within existing textbooks as well as the equivalent structure or reverification from the task analysis, the instructional strategies focused on the conveyance of appropriate learning expectancies to the students via various types of media presentations. As will be elaborated in the next section on media selection, distinctive instructional strategies were utilized for each of the sub-sections of a lesson.

First, each textbook reading assignment was followed by a detailed CAI quiz which had a specified criterion performance level. If a student failed to meet criterion, he was given a remedial reading assignment and recycled through the quiz items. This strategy insured that the students' comprehension of the text was more than sufficient. In regard to the audio lectures, a set of typed notes and diagrams were utilized in conjunction with the audio tapes. The concepts presented in the audio lectures again were evaluated in terms of CAI quizzes. For remedial purposes, students were encouraged to repeat the presentation if their performance did not meet criterion. For both the PSSC conceptual film presentations and the laboratory film loop presentations, there were related CAI quiz items. Again, students were directed to return to the presentation if their performance was not at or above the desired criterion level.

In each of the lessons, the final assessment of the behavioral objectives was in terms of a CAI problem set. Students were provided detailed remediation within the structure of each of the problems. As a follow-up, a parallel form of the physics problems was presented as review material prior to both the midterm and final examinations. These CAI review problems again assessed the long-term retention of the behavioral objectives for each of the lessons.

In essence, the instructional strategies were created in order to relate hypothesized sets of psychological states through which the student would pass while completing various tasks in each of the physics lessons. In this regard, the students were provided a recognition of the learning expectancies to be covered within each of the sub-sections of the physics course. This was accomplished via explicit directions plus criterion quizzes at the end of each sub-section. These psychological expectancies provided involvement and commitment on the part of the student to obtain the desired behavioral objectives. Without this psychological commitment, there would be a low probability that the CAI instruction would produce the desired optimal learning outcomes.

Having gained the student's involvement, the new information of each lesson must be sequenced in light of the prior knowledge and problem-solving skills gained in prior lessons by the student. The algorithms of these problem-solving skills are clearly related to the specific sub-concepts of each topic in the physics course. For example, the solution of kinetic energy problems related back to considerations of the sub-concepts of force and matter. If a student had mastered the sub-component elements of each concept, then the more complex algorithms could be applied.

As a last feature of the instructional strategy, an attempt was made to provide frequent conceptual closure and the self-realization by the student of having gained competency over each specific topic in the course. This psychological requirement for frequent closure is one of the most overlooped aspects involved in effective instructional strategies.

6. Media Assignment. As a related aspect of the development of the automated physics course, the process of assigning appropriate media for each concept is critical. Most of these decisions are typically based on relatively unexplored research conceptions. Obviously, the media utilized for a given presentation has to be as contiguous or as similar to the response modality as possible. The physics course utilized a wide variety of multi-media modalities. Rather than restricting the presentation only to the CAI-CRT terminal device, the most appropriate match between the media and the information features of the concepts was attempted. This use of multi-media within the physics course offered an opportunity to analyze the learning impact of these media types. The effectiveness of various media is an important part of the research findings and, as such, is reported in sections VIII and IX.

The following guidelines were used for media selection. First, when attempting to facilitate acquisition of conceptual material, the use of multiple sensory channel inputs was maximized. For example, in presenting a complex demonstration of physical phenomena like kinetic energy, either PSSC films or film loops were used in order to maximize the richness of the sensory characteristics. Second, when allowing for both acquisition and intellectual problem solving, the information source was focused within restricted sensory channels. For example, many problem-solving routines were illustrated within the audio lecture through the use of accompanying graphic presentations. Third, when attempting to build problem-solving skills for long-term retention, the use of feedback and correction via CAI was maximized. The interactive feature of the CAI system was utilized in order to individualize the feedback, the correction, and to insure sufficient practice. Fourth, when faced with evaluative decision-making, especially in determining successful attainment of the behavioral objectives, the real-time student history feature of the CAI system was utilized in order to scan over a number of learning tasks in determining an appropriate decision about criterion performance. And lastly, the logistics of the instruction from the students' point of view in moving from one media device to another was considered. While interruptions may break the monotony of the instructional process, it has been found that interruptions within learning processes can interfere with acquisition and retention. Thus, an attempt was made to match appropriate media in order to have a smooth flow through a given lesson.

7. Field Tests. In conducting the field tests and subsequent revisions, the following factors seemed important based upon our experiences. First, appropriate selection of students who vary according to aptitude, prior knowledge, and other psychological characteristics is difficult to obtain but important. The forming of special sub-groups to assess their reaction to the materials formed the substance of all future revisions in the CAI physics course. Secondly, the importance of looking at learning frame statistics as well as overall course performance became quite contingent upon our ability to process and analyze the CAI data encoded within the computer system. As will be explained in a subsequent section, a computer data analysis and management system was developed in order to perform these analyses. Various reports proved invaluable to the course authors in the revision process and should be considered an essential part of any computer approach to instruction. Third, good interview techniques should be employed constantly, not just at the end of the course, but throughout the instructional process. Informal comments from students can be treated as hypotheses which need to be checked out as to their validity and potential implications for course change. The informal comments from students concerning scheduling and the reliability of various media devices indirectly formed the basis upon which certain equipment and scheduling changes were made in the CAI physics course. Lastly, a pool of experienced personnel with clear understandings of their functions is required when one is pursuing development work in computer approaches to instruction. For example, the primary function performed by the student proctors was one of assistance to the students, but more importantly they served as input sources by which important information was gained both through direct observation of and interactions with the students.

8. Field Study and Project Development Schedule. Table 1 presents a brief quarter by quarter description of the primary project activities. It can be observed that most of the first year was devoted to developing the course. The complete course description can be found in section IV. The CAI physics problem exercises, which were offered during six quarters, are reviewed in section V. The first field study which was conducted in the fall of 1967, is described in section VI. The second field study, the most complete of the experimental versions,is described in section VII. The final field study that focused on group discussion outcomes is described in section VIII.

Table 1

Developmental Schedule for the Project

	First Year, (1966-7)	Second Year, (1967-8)	Third Year, (1968-9)
Fall	Project Initiation Staffing, CAI Problem Exercises, Course Analysis	First Course Field Test, CAI Problem Exercises	Flex Field test
Winter	Video recording, (1967), CAI Problem Exercises, Task Analyses Entry Behaviors	Data Analysis, (1968) Course Revision	Data Analysis, (1969) Final Report, Project ended
Spring	CAI Problem Exercises, Behavioral Objectives, Film Preparation, Course Authoring	Second Course Field Test CAI Problem Exercises	
Summer	CAI Coding, Audio Loop Preparations, Graphics Preparation, CAI Problem Exercises	Data Analysis, Course Revision	

9. Management Techniques. The primary task in the management of the project consisted of evolving and redefining the functional roles for staff personnel. As new needs and related functions were identified, a staff member assumed the responsibility and in essence created the role. The primary mechanism for planning and coordinating was a weekly staff meeting. While more formal project planning techniques like PERT might have improved the project's development, the unknown nature of the CAI course development process resulted in the use of more informal planning and communication techniques. However, the use of the Systems Approach as a model for CAI curriculum development is highly recommended.

10. Roles Within a Physics CAI Project. Any CAI project utilizing a rich array of technological equipment requires a complex functional organization that differentiates roles and related competencies. This section of the report describes the various roles which evolved within the physics project.

11. Content Scholars. Foremost within a CAI project is the requirement for excellent subject matter scholars who have complete command of the concepts to be taught. The project was fortunate to have the involvement and professional commitment of four professors from the Florida State Department of Physics, namely, Drs. Steve Edwards, Guenter Schwarz, Neil Fletcher, and William Nelson. While the project did not create a major new sequencing of the concepts of physics, each of these men provided excellent insights within the following phased steps.

First and foremost, Dr. Edwards and Dr. Schwarz devoted innumerable hours to the preparation of a detailed conceptual outline of the course. In addition, Dr. Edwards allowed us to video-record his classroom presentations over two successive quarters. These video recordings were used to study the language and demonstrations utilized in these lecture presentations. As various segments within the CAI course were developed, each of the four professors provided valuable contributions in terms of critiquing and editing the course materials. Since these materials were automated, these professors went through them in a student mode in order to detect any misconceptions or inaccuracies. In addition, Professor Edwards provided invaluable service in the continual preparation of new sets of midterm and final examination questions as well as the homework assignments for the physics class. It should be noted that a common set of examinations and homework problems was utilized in comparisons between the conventional and CAI versions of the course.

Informally, these physics professors also contributed to the development of the field studies by lending professional support to the process of gaining permission to teach the CAI version for full university credit. While this may seem like a minor point, one should not minimize the time and energy required to gain permission to offer credit for an experimental instructional course. Typically, the university administrators wish the assurance that the "new" course will be equivalent to or better than the existing course. Prior to the first field study, as many arguments as possible for accrediting the course were assembled with the knowledge that the empirical outcomes might in fact refute some of the claims. High student acceptance and positive outcomes from the CAI problem exercises (reviewed in section V) were emphasized. More importantly, Professor Edwards actively supported and recommended the acceptance of the course presentation even though the following restrictions were imposed by the Department of Physics as well as the Dean of Arts and Sciences.

1. The course instructor will retain final editing control of all the CAI physics materials.

2. If, in the judgment of the course instructor, this field test is proving to be disadvantageous to the students, he will terminate the experiment at that point.

3. Qualified physics proctors will be available during all instructional settings.

4. The derivation of grades will be from a common set of examinations given to both the CAI and conventional students.

Fortunately, all of the physics professors supported these points and worked cooperatively to make the project a successful one. Thus, the physics professors participated in both conceptual and implementing roles.

12. Behavioral Scientist. An equivalently important talent is represented by the behavioral scientists who provided insights into the overall creation and implementation of the systems approach. Being "behavioral methodologists," the behavioral scientists provided reasonable criteria for the behavioral consequences of the instruction. They also analyzed the issues dealing with the topics of entry behaviors, task analysis, behavioral objectives, and instructional strategies. Concurrently, the behavioral scientists contributed the major structure of the research design as well as specific hypotheses which are reported within the field studies. Since they had prior experience with experimental data analysis, the responsibility for analyzing the instructional outcomes and interpreting them also was assumed by the behavioral scientists. Perhaps most importantly the behavioral scientists provided the managerial leadership and the training of other personnel within the project in order to achieve the project goals. The principal behavioral scientists were Duncan Hansen, Walter Dick, and Henry Lippert. Many of the graduate students, resident in the CAI center, also participated in some of the roles described above.

13. Physics Writers. Since the talents of both the professional physicist and behavioral scientists are in exceedingly short supply, the project recruited a full-time physics writer. After being trained in the nature of CAI and the desired instructional strategies, plus viewing the video tapes for appropriate language, the full-time writer, as well as three parttime physics graduate students, proceeded ahead with the detailed writing of the instructional materials. Thorough command of the physics content and an understanding of the overall systems approach and computer capabilities were required. The majority of the writing was performed by these authors. It can be recommended that such full-time writers form an essential ingredient in a reasonably large CAI developmental project.

14. CAI Coders. After the instructional material had been edited, a CAI coder entered it into the IBM 1500 CAI system. The CAI coder had a thorough understanding of the Coursewriter II language, the uses of switches and counters for real-time data analysis, and the role of macros which provide a method for more quickly encoding curriculum materials. The CAI coders, who are excellent typists, typically performed both the entry and copy editing functions; that is, many minor mistakes were picked up by these coders and referred back to the physics writers and the physicists. This type of informal editing can be exceedingly important within the implementation phase of CAI.

15. Media Specialists. In terms of the physics projects, part-time media specialists were employed who helped in the preparation of the concept films as well as the audio tapes. Since a random access audio system was available for this project, instruction in the preparation of tapes was required. While no special or unique functions evolved for these media specialists, they did prepare all of the final version of the curriculum.

16. Computer Operators. As the physics course was being encoded by the CAI coders, a computer operator had to be available for supervision and normal back-up operations on the computer. The primary contribution of the computer operator was in terms of solving linkage failures within the CAI courses. These linkage failures are computer errors which drop required indices that correctly link up various branched parts of a CAI course. In addition, the computer operators kept a very extensive set of records as to the nature of the CAI operation and scheduled work loads, so that appropriate materials were available for all students.

17. Computer Systems Programmers. In the process of developing the course, it was necessary to employ a computer systems programmer who developed the FSU Data Analysis and Management System. (This will be described in the next section.) In addition to designing overall systems for CAI operations (e.g., more effective ways of encoding materials for data analysis, or more effective reports for authors and investigators), the computer systems programmer focused on the logistics of the total computing system. Resolving certain logistics problems, such as the requirement for extensive course listings, etc., has been very important within the CAI context in order to insure prompt processing of all requests. Moreover, the systems programmer has developed special Coursewriter functions that allow an author to gain the kinds of information and branching flow desired within the instructional sequence. Thus, the overall computer system was vastly improved by the computer systems programmer.

18. Data Analysis Programmer. Repeated data analyses, especially in terms of item frames, was required as a critical part of the project. This function typically involved taking data from the CAI data management system and processing it on any of the computers on the FSU campus. While many of these statistical programs such as items analysis

and linear regression were available, the preparation of new input/output statements were a special requirement for the project.

19. Proctors. As mentioned in the description of the field study, a proctor is necessary to supervise the actual mechanics of CAI instruction. The primary activity in the physics project was assisting students in preparing various media devices for actual utilization. Proctors were recruited who had competencies in physics in order that they could assist students with conceptual problems. However, these problem-solving requests were so infrequent as to be almost non-occurring. In addition, the proctors kept extensive observational notes and performed interviews which provided a great deal of information related to the students' adaptation to the multi-media CAI physics course.

20. Graduate Students. Within any large CAI curriculum development project there should be an array of graduate students who can provide at least two significant contributions. First, the graduate students represent excellent back-up personnel and superior problem-solvers. The physics project was inundated with a multitude of small problems and our graduate students learned a great deal by resolving them. More importantly, though, the graduate students continually raised questions about the overall systems approach and generated small research experiments related to major questions revolving around instructional strategy and media selection. This small-scale experimental research performed on other content topics provided important information during the formative stage of this project. Thus, it is felt that the support and active involvement of graduate students is an important ingredient in the overall mix of functional roles in a complex CAI project.

21. Data Analysis and Data Management. As a result of the need for data analysis in the CAI physics project, a general file structure system was developed that allowed for the organization of each student's behavioral responses into a clearly identifiable file array. This general file structure is an exceedingly important feature in data analysis for a number of reasons. First, authors tend to be primarily interested in item or frame statistics. The file structure must be manipulatable so that item and frame statistics can be printed out in a number of ways in order to characterize performance and allow for easy inference making in the revision process. As a corollary, the quick availability of this information for the authors is exceedingly important. Secondly, the file structure must be amenable to comparative analysis for various portions of the course, or various media presentations. These comparative analyses permitted the project team to decide whether certain hypotheses were in fact valid and worthy of further pursuit.

In terms of more sophisticated analyses, a number of factorial and linear regression techniques were utilized in order to obtain both within and across group comparisons. The data file structure was organized in a matrix fashion in order to generate variance and covariance matrices which could be utilized within these regression models. These linear regression analysis techniques are extremely useful in gaining insights into the identification of variables which are important in terms of positively influencing the performance levels resulting from the instruction. (A more detailed description of the Data Analyses and Management System can be found in Appendix B.)

One of the great potentials of CAI data is the sequential tagging of each student's response. The sequential analysis of responses has proven to be of considerable difficulty and the FSU CAI Center is still developing programs to allow for more adequate analysis of sequential responses as well as latencies. Ultimately, it is hoped that these analyses will eventuate into quantitative models that characterize the learning process. Unfortunately, the complexities of the analysis have prevented this avenue from being pushed much beyond the linear regression models. (See the reports in sections VI and VII.) Thus, it is felt that the investment in and development of the Data Analysis and Management System was an important ingredient for the successful completion of this project.

C. University Professorial CAI Projects

As part of the overall research design, the project sponsored a limited number of university professors who investigated the use of CAI for instruction within their own disciplines. The study concerned the productivity and techniques evolved by the professors as opposed to the systems approach evolved by the physics project. As will be portrayed in the results in the following description, it is clear that the professors consistently pursued the conventional research model employed in the more classic areas of research, i.e., they pursued limited objectives and primarily depended upon their graduate students to implement the research endeavor.

In terms of productivity, Table 2, page 29, presents the information concerning the course topics and student time generated by these university professors. It is worth noting that in all cases the work was, in fact, performed by a graduate student supported by the project or by the professor. Moreover, all of the endeavors are relatively short instructional sequences varying between 30 minutes and 4 hours. While one or two experimental studies were performed in each case, the ultimate follow-up was quite limited and the impact on the instructional activity at FSU was also exceedingly limited. By not utilizing the systems approach, the research studies seemed to lack the trained manpower to implement the intended goals.

While espousing the desire to develop total courses, the lack of training on the part of the professorial member presented many communication problems. First, in many cases, the computer coding had to be redone because there was a lack of clear specificity, especially with regard to behavioral objectives and the desired instructional strategy. Secondly, these professors, in many cases, presented scheduling difficulties in that they had little managerial experience in predicting when their materials would be ready for use by students. Lastly, their efforts in analyzing the results were primarily limited to pre- and posttest types of analyses more conventionally found in non-CAI investigations. On the other hand, it should be pointed out that the quality of the learning materials developed was exceptionally good and represents a set of prototypic materials in a wide range of content areas. The main conclusion from these CAI developmental studies by independent university professors was that any significant CAI curriculum development effort should utilize the systems approach and needs a sufficient amount of competent manpower in order to implement an entire course.

Table 2

Courses Developed by Florida State University Professorial Staff

Name - Department	Course Title	Student Time	Intended Population
Marian Black Educational Administration	General Curriculum Study (curpa)	6 hours	juniors, seniors and graduate students
Walter Dick Educational Research	Experimental Test on Reliability and Validity Programs (reval)	2 hours	graduate students
Don Driggs Psychology	Comparison of Constructed Response and Multiple Choice Response Moded on Beginning Psychology Learning Materials	4 hours	beginning psychology students
Walter Ehlers Social Welfare	Concepts of Social Welfare	4 hours	graduate students in social welfare
Walter Ehlers Social Welfare	Concepts of Social Welfare Work (consowel)	6 hours	graduate students in social welfare
Duncan Hansen Educational Research & Psychology	The Affects of Idiosyncratic Reinforcement Conditions on Learning Acquisition of a Complex Numbers Program (complex) (comnumst) (comnumii)	4-5 hours	9th graders
John Healy University Laboratory School	Computation with Fractional Numbers (compfrac)	6 hours	7th & 8th graders needing assistance with fractional numbers
Ivan Johnson Art Education	Examples of Architectural Style (arthis)	1 hour	elementary school teachers
Robert Kalin Math Education	Introduction to Set Theory (espig)	2 hours	freshmen
Robert Kalin Math Education	Use of a Computer for Teaching Deductive Reasoning (deduct)	30 minutes	high school students

Table 2 - continued

Name - Department	Course Title	Student Time	Intended Population
Robert Kalin Math Education	A Comparison of Two Methods of Presenting an Axiom System (proof)	4 hours	college freshmen in math education classes
F. J. King Educational Research	Auditory-Visual Stimulus Redundancy in Concept Identification (auviscon)	8 hours	college undergraduates
E. P. Miles Math Education	CAI Applied to Basic Computer Programming (fortran)	4 hours	college sophomores interested in computer applications
E. P. Miles Math Education	Introduction to Computer Programming with Autocoder (ms200)	4 hours	same as fortran
Gerald Miller Educational Research	Pedant--Programmed Exercise in Divergent and Normal Thinking (hogan)	30 minutes	junior high students
Wayne Minnick Speech	An Experimental Study in Broadcast Communication (televis)	1-1½ hours	college seniors, majors in broadcast
Ray Schultz Higher Education	An Investigation of the Application of Computer-Assisted Instruction and Information Retrieval Systems to Academic Advising in a Junior College (advise)	2 hours	Tallahassee Junior College students
Guenter Schwarz Physics	Physics Laboratory Experiments Using CAI (pslab)	undetermined	university freshmen
Tim Smith Psychology	The Role of Incorrect Responses, Explanation and Student Pairing on the Learning of Programmed Text Material (psyed)	45 minutes	college sophomores
Tim Smith Psychology	Interaction of Examiner Attitude with Praise and Blame (thesi)	1 hour	college sophomores
Tim Smith Psychology	Effects of Three Instructional Strategies on Achievement in a Remedial Arithmetic Program (addsub)	3 hours	junior high, low achievers in math

Table 2 - Continued

Name - Department	Course Title	Student Time	Intended Population
William Snyder Science Education	Use of CAI in Science Instruction	2 hours	eighth graders
Charles Spielberger Psychology	Paired-Associate Learning (pal)	1½ hours	psychology department students
Howard Stoker Educational Research	Algebra Review (algw2)	undetermined	
Howard Stoker Educational Research	Individual and Group Differences in Learning under Two Different Modes of CAI (edtest)	3 hours	seniors in the school of education
Howard Stoker Educational Research	Instructional Materials to be used in Educational Measurement Courses (teststat) (testref)	6 hours	college seniors and graduate students in educational measurement

D. Summary

Briefly, the following eight factors seem critically important in determining the rate of development and success of a computer-based curriculum project:

1. The use of the systems approach and the clarity of the behavioral objectives derived for the CAI curriculum will determine the rate with which a project will be developed.

2. The variety and frequency with which varying response modalities such as speech, light pen, keyboard, etc., are required in a course can affect the rate at which a CAI curriculum can be implemented.

3. Terminal criterion performance levels for the CAI course will determine both the instructional sequence as well as the complexity of the instructional strategy. In turn, the complexity of the instructional strategy will determine the developmental rate of the project.

4. The variety of multi-media utilized in the CAI course will determine the implementation rate and the logistic ease of the instructional process.

5. The number of revision cycles required to develop an "optimal version" of a CAI course remains an unanswered question. However, the use of CAI problem sets to determine baseline performance and video recordings of excellent instruction in a conventional setting allowed for restricting the number of revision cycles.

6. The degree of sophistication of the CAI operating system is highly critical in determining the rate of development. The availability of an efficient coding language with macro techniques plus an operative computer data analysis and management system is highly essential for a favorable rate of development.

7. The number of experimental versions of the CAI course will determine the rate with which the project successfully reaches closure. However, investigation of experimental issues is necessary for the full evaluation and validation of the curriculum.

8. Since it is recognized that CAI curriculum development is a highly complex process, the use of multiple role differentiation techniques and specific functional assignments for staff members leads to more effective and efficient rates of development.

IV

DESCRIPTION OF THE MULTI-MEDIA COMPUTER-BASED PHYSICS COURSE

A. Introduction

The Florida State University CAI physics course utilized a wide variety of media approaches. Rather than restricting the informational presentation to the CRT terminal devices of the 1500 CAI system, we chose to select suitable media by employing the criteria described in the prior chapter. This feature of the physics course provided an opportunity to analyze the impact of these media types on concurrent concept acquisition behaviors as well as on final examination performance. Thus the physics course provided information about the relative efficacy of a variety of media approaches.

B. Course Flow

The CAI physics course followed the same general content outline as the companion course taught by lecture. The CAI students were allowed to schedule their own time at the CAI center. At the center, their progress was directed by the computer program. This presentation was via a cathode ray tube (CRT, a television-like screen) with an associated typewriter keyboard. Problems and instructions to the student were displayed on the CRT. The student could indicate his response to the computer by typing his answer on the keyboard or by touching a light pen to the appropriate location on the CRT.

A typical lesson in the course began with the student reporting to the computer terminal and taking a short quiz based upon his reading assignment. If the student did not pass the quiz, he was instructed to reread the material and return to take the quiz again. If he was successful, the student was directed to listen to a short lecture on the major topic of the lesson. A special cartridge system provided the audio lecture for the students at their terminals. The student was also provided with an outline which included helpful drawings relevant to the lecture. After completing the lecture, the student was quizzed via the terminal on the audio presentation. The student was then directed to a single concept film loop or a PSSC film. The single concept film loop presented demonstrations of some of the major concepts included in the lesson. Outlines were also available for the film loops. If the student was directed to view a PSSC film, he would notify a proctor who in turn would operate the film projector. The student then returned to his terminal to take a short quiz on the film. Based upon the lesson content, the student might be directed to other presentations on various media. At the completion of the entire sequence of instruction, the student was given his next textbook assignment.

Special midterm and final examination reviews were available on another computer system, the IBM 1440. Since this system utilized only a typewriter terminal, the student-computer dialogue was typed.

The 1440 system had the advantage of providing the student with a printout of his review. Students from the lecture courses also were allowed to use this computer review. Two sets of paper and pencil practice homework problems were also assigned, one before each examination.

Most of the CAI students averaged about two lessons per visit to the Center; the range was from one to eleven lessons. The only constraint placed upon the students in regard to time was that they had to reach the halfway point in the course by the time of the midterm examination and complete the course by the date of the final examination. The same multiple choice tests were given to the CAI and lecture classes. Table 3 presents a lesson outline which includes the lecture topics and film assignments. Table 4 provides a "course flow" comparison of the conventional lecture course with the autonomous multi-media computer-based course.

C. Description of Media

1. Textbook. Both the CAI and lecture classes were given the same reading assignments in Elementary Physics by R. W. Van Name, Jr., In the preface of the book the author describes the objectives and content of the text. This book presents the central ideas of physics without using any mathematics more advanced than simple algebra. It is especially designed for the one semester or one quarter course usually offered to non-science majors. The main ideas of each chapter are applied to everyday situations so that the student's interest will be aroused as he is able to relate physics to the world in which he lives. This world unceasingly obeys the laws of physics.

Table 5 presents the lesson outline for light and optics. Each outline includes a description of required prior knowledge, concepts under study, behavioral objectives, and a diagram of the media of presentation. Appendix C contains outlines for each of the twenty-nine lessons. Examples of the reading quiz questions which were based on the Van Name text can be found in Appendix D .

2. Computer Interaction and Management. As stated above, the CAI computer system functioned primarily as a pacing, quizzing, interacting, and record-keeping tool. The first activity the student generally performed at the terminal each day was to respond to a four to six-item quiz which covered the textbook assignment which was given to the student at the end of the previous lesson. At the end of this quiz, the student's score was displayed on the screen. If he did not answer the minimum number of questions correctly, the computer instructed him to sign off and come back when he was better prepared to pass the reading quiz.

Table 3

CAI Multi-Media, Computer-Based Physics Course
Materials Used in Each Lesson

Lesson Number	Lecture Number	Lecture Subject	PSSC Film No.	 Title	Concept Film Loops* No.	 Title
1	1	Intro. to CAI and Course				
2	2	Measurement	104	Measuring Short Distances		
3	3	Scaling	106	Change of Scale		
4	4	Vectors				
5	5	Atoms and Molecules	113	Crystals	80-296	Properties of Gases
6	6	Light: Reflection, Refraction, Images	201	Intro. to Optics	FSU-24	Reflec. & Refract. of Light
7	7	Particle Model of Light	203	Speed of Light	FSU-23	Reflect. & Refract. Particle Model
8	8	Wave Properties; Reflection Refraction	204	Simple Waves		

* Film loops are from Ealing Company unless marked FSU.

Table 3--Continued

CAI Multi-Media, Computer-Based Physics Course

Materials Used in Each Lesson

Lesson Number	Lecture Number	Lecture Subject	PSSC Film		Concept Film Loops	
			No.	Title	No.	Title
9	9	Waves; Interference, Diffraction			80-206	Diffraction, Single Slit
					80-207	Diffraction, Double Slit
					80-241	Effect of Phase Diffraction Between Sources
					80-244	Diffraction & Scattering Around Obstacles
10	10	Forces and Vector Review	301	Forces		
11	11	Newton's Law, Inertia	302	Inertia	** FSU 17	I Fun and Games
					** FSU 18	II Using Inertia
					** FSU 19	III
12	12	Weight and Mass	303	Inertial Mass		
13	13	Forces, Acceleration	305	Deflecting Forces		

* Film loops are from Ealing Company unless marked FSU
** Optional

Table 3--Continued

CAI Multi-Media, Computer-Based Physics Course

Materials Used in Each Lesson

Lesson Number	Lecture Number	Lecture Subject	PSSC Film No.	PSSC Film Title	Concept Film Loops* No.	Concept Film Loops* Title
14	14	Satellites, Planets	307	Frames of Reference		
15	15	Momentum			FSU-38	Conservation of Momentum Rocket
16	16	Kinetic Energy, Work	311	Energy and Work	FSU-31 or 80-277	Conservation of Linear Momentum (Billiard Balls) Conservation of Linear Momentum; Elastic Collisions
17	17	Potential Energy				
18	18	Energy Conservation	313	Conservation of Energy		
19	19	Electricity	403	Coulomb's Law		

* Film loops are from Ealing Company unless marked FSU.

[illegible], Computer Based Physics Course,
Materials Used in Each Lesson

Lesson Number	Lecture Number	Lecture Subject	PSSC Film No.	PSSC Film Title	Concept Film Loops* No.	Concept Film Loops* Title
20	20	Electrostatics			80-281	Intro. to Electrostatics
					80-283	Electrostatic Induction
					80-290	Problems in Electrostatics
21	21	Charge on the Electron	404	Millikan Experiment		
22	22	Electric Energy, Currents	409	Elementary Charges and Transfer of Kinetic Energy		
23	23	Magnetism			FSU-34	Magnetic Force on a Current
					FSU-35	Torque on a Magnet
					FSU-36	Torque on a Coil
					FSU-33	Magnetic Field Near a Wire

* Film loops are from Ealing Company unless marked FSU.

Table 3--Continued

CAI Multi-Media, Computer-Based Physics Course,
Materials Used in Each Lesson

Lesson Number	Lecture Number	Lecture Subject	PSSC Film		Concept Film Loops*	
			No.	Title	No.	Title
24	24	Induction			FSU-10	Eddy Current Damping
					FSU-11	Induced EMF: Wire Moving Through Magnetic Field
					FSU-14	Induced EMF: Moving Magnetic in Coil
					FSU-15	Induced EMF: Two Coils
					FSU-20	Induced EMF: H.F. Richards Apparatus
					FSU-30	Induced EMF: Lenz's Law and the Jumping Rings
					FSU-32	The Galvanometer

* Film loops are from Ealing Company unless marked FSU.

CAI Multi-Media, Computer-Based Physics Course,
Materials Used in Each Lesson

Lesson Number	Lecture Number	Lecture Subject	PSSC Film No.	PSSC Film Title	Concept Film Loops* No.	Concept Film Loops* Title
25	25	Electromagnetic Waves, Mass of the Electron	413	Mass of the Electron	FSU-13	Microwave Radiation
26	26	The Rutherford Atom	418	Photons		
27	27	Photons	419	Interference of Photons		
28	28	The Bohr Atom	421	Franck-Hertz Experiment		
29	29	Quantum Theory, Modern Physics				

* Film loops are from Ealing Company unless marked FSU.

Table 4

Outline Comparison of CAI Course with Conventional Course

Conventional Course	CAI Course	**
Number of Students: 200 per section, three sections	23 students (Fall, 1967) 37 students (Spring, 1968)	
Textbook Reading Assignments	Textbook Reading Assignments (same)	
	Quiz on Assigned Reading Before each lesson. Student must pass before continuing lesson.	**
Lectures (28 to 30) (a) lectures (b) demonstrations (c) blackboard notes: equations, diagrams, key concepts, etc.	Lecture (29) (a) audio lectures on tape (b) 4-minute concept film loops (c) booklet of mimeographed supplementary sheets	
	Quiz on lecture contents: conceptual and quantitative questions	**
PSSC Films (about 20)	PSSC Films (same)	
	Quiz on ideas presented in PSSC films	**

** Indicates activities at 1500 computer terminal

Table 4 - Continued

Outline Comparison of CAI Course with Conventional Course

Conventional Course	CAI Course	**
Homework Problems: two sets Not collected or graded	Homework Problems: (same)	
"Outside" help available: (a) graduate students with (b) CAI review on 1440 system	"Outside" help available: (a) proctors at CAI center (b) CAI review on 1440 system	
Midterm and final exams (multiple choice) determines course grade	Midterm and final exams determines course grade (same); may be taken earlier than regularly scheduled date if desired. May not be taken after given in conventional course.	

** Indicates activities at 1500 computer terminal

Each audio lecture was also followed by a quiz at the terminal. The quiz consisted of six to ten questions, some of which were conceptual while others were quantitatively oriented. Most questions were multiple choice, but some required a keyboard (constructed) response. A hint could be obtained by pressing the "hint" display with the light pen for a multiple choice light pen question, or by typing "hint" for keyboard response questions. If the student answered incorrectly, the computer provided him with some remedial instruction, including some suggestion about the correct solution, then told him to try again. The performance criterion established in the instructional logic of the program required a correct answer from the student before he could proceed to the next question. A record of his responses was kept for later data analysis, but no "score" for the lecture quiz was displayed on the screen as was the case for the textbook quiz.

After each PSSC film, the student returned to the computer terminal for a quiz (typically from four to six questions) on that film; these questions were designed to focus attention on the main ideas presented in the film. As in the lecture quiz, it was necessary to answer each question correctly before moving on to the next question. At the end of each lesson, the computer gave the text reading assignment for the next lesson and instructed the student to sign off.

3. Audio Lecture and Notes. In the first field study (Fall, 1967), ordinary tape recorders were used for the audio portion of the course; in the second field study (Spring, 1968), the tapes were placed in cartridges and played on an RCA Experimental Audio System. Earphones were provided at each computer terminal. The students in the second field study thus did not have to leave the terminal room to hear a lecture; however, they lost the ability to stop or back up the lecture tape which was an advantage of the regular tape recorder which was used in the first field study. The student could of course replay the cartridge at its completion. The content of the audio lecture was equivalent to that of the conventional course, but special arrangements had to be made to replace lecture demonstrations, and the blackboard notes and diagrams which were utilized by the classroom lecturer.

A classroom instructor normally writes down equations, key phrases, and concepts as he lectures to a class; therefore, it was felt that some visual reinforcement was necessary for the CAI audio lectures also. For this purpose, a booklet of "supplementary sheets" was prepared and given to each student to use primarily while listening to the lecture. A complete set of these notes are provided in Appendix E . Some blank spaces were provided on the sheets in order that the student could take additional notes if he desired. Some students looked over these sheets before hearing the lecture and most used them for review before taking examinations. Table 6 presents an example of the notes for the audio presentation on optics. Many students commented that this booklet was one of the most useful aids in the course.

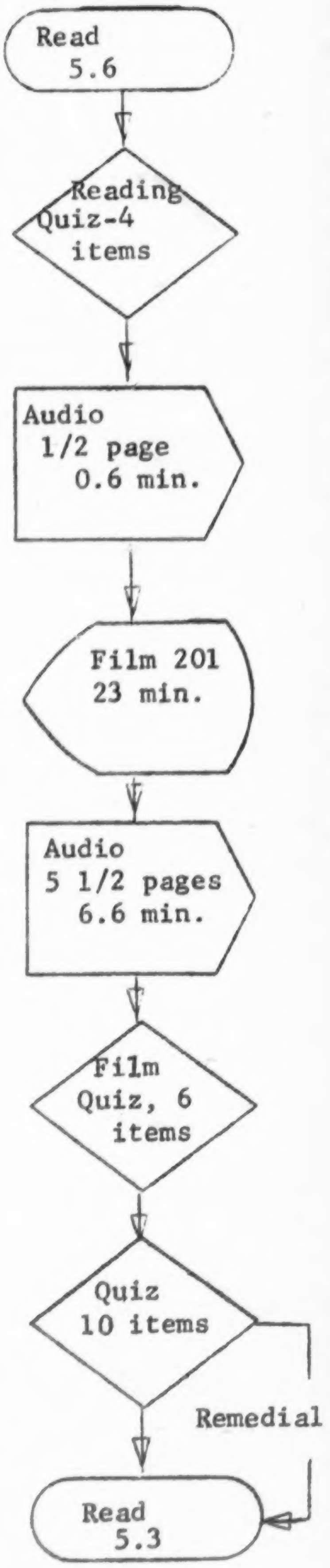
4. Concept Film Loops. Four-minute "concept" film loops, packaged in cartridges, were utilized to provide the CAI students with the demonstrations usually coordinated by the classroom lecturer. A description of each of these film loops may be found in Appendix F. At the appropriate place in the audio lecture, the student was directed to watch a particular demonstration by inserting a cartridge in a technicolor super 8-mm. projector. (This device is extremely simple to operate.) Twenty-seven of these film loops were used; eight were purchased commercially, but most were prepared by a Florida State University physicist, Dr. Guenter Schwarz. Copies were made, inserted into cartridges, and added to the film library at the CAI center. The films are in color, but do not have sound. They have the advantage of both providing a close-up, detailed view for each student, plus reliability--there were no worries about whether the demonstration would work. Also, the film could be viewed as many times as desired. The major disadvantage of these film loops, when used without an instructor, is the lack of a simultaneous explanation of what is taking place in the film. In the second field study of the course (Spring, 1968) this weakness was overcome by having mimeographed notes for each of the film loop demonstrations. The students would study these notes before and during their viewing the film loops. Table 7 provides an illustration of these notes for the film loop on optics.

5. PSSC Films. Twenty of the twenty-nine lessons included a PSSC film which had running times of approximately twenty to thirty minutes. Some of these films were in color while the remainder were in black and white. The titles and descriptions of these films can be found in Appendix G .

Table 5

Sample Lesson Flow Diagram and Explanation

Lesson Number: 6
Lesson Title: Introduction to Light and Optics



Lesson Goals:

Introduction to light and optical phenomena.

CONCEPTS PREVIOUSLY NEEDED AND ACQUIRED:

Vectors and vector algebra--a vector is a quantity having both magnitude and direction. Familiarity with vector addition.

CONCEPTS TO BE ACQUIRED:

Light travels in straight lines.

Four ways in which light may be bent:

1. reflection--light reflected from a plane surface will have equal angles of incidence and reflection;
2. refraction--light traveling through two transmitting media will experience a change in the path according to Snell's Law - sin i/sin r = n_r/n_i;
3. scattering--reflection or refracting light so as to diffuse it in many directions;
4. diffraction--modification that light undergoes when passing the edge of an opaque body.

Properties of light and optical phenomena:

1. Images-- visual counterpart of an object formed by a mirror or lens;
2. real images--light rays appear to converge at the image; image may be detected on an opaque surface;
3. virtual image--no light rays actually pass through or originate at the image;
4. inverted and perverted images-- perverted--right and left sides of image interchanged; inverted--top and bottom of image are interchanged.

Behavioral Objectives:

What is the relationship between the angle of incidence and the angle of reflection for light reflected from a plane surface? (They are equal.)

Table 5--Continued

What are the characteristics of the two basic types of images? (real and virtual)

What are the describing characteristics of inverted and perverted images?

Describe four ways in which light can be "bent."

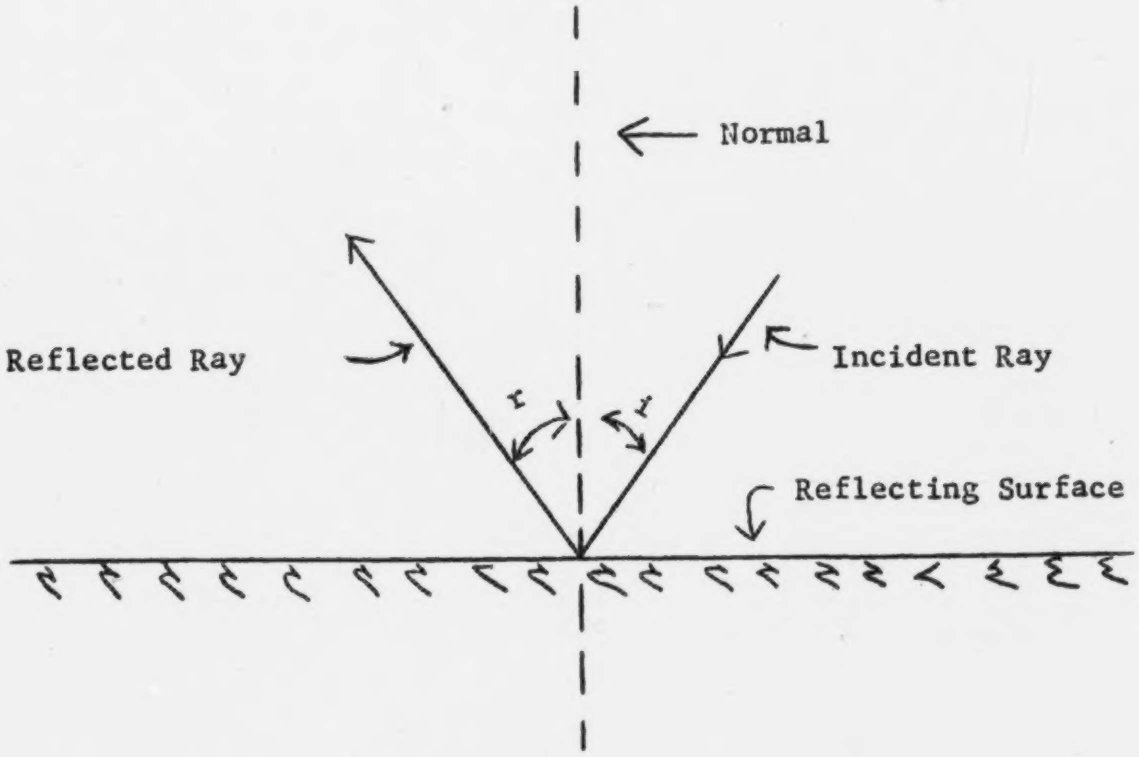
Table 6

Outline of Audio Lecture 6

I. The incident ray, the normal, and the reflected ray all lie in the same plane.

II. The angle of incidence, i, is equal to the angle of reflection, r.

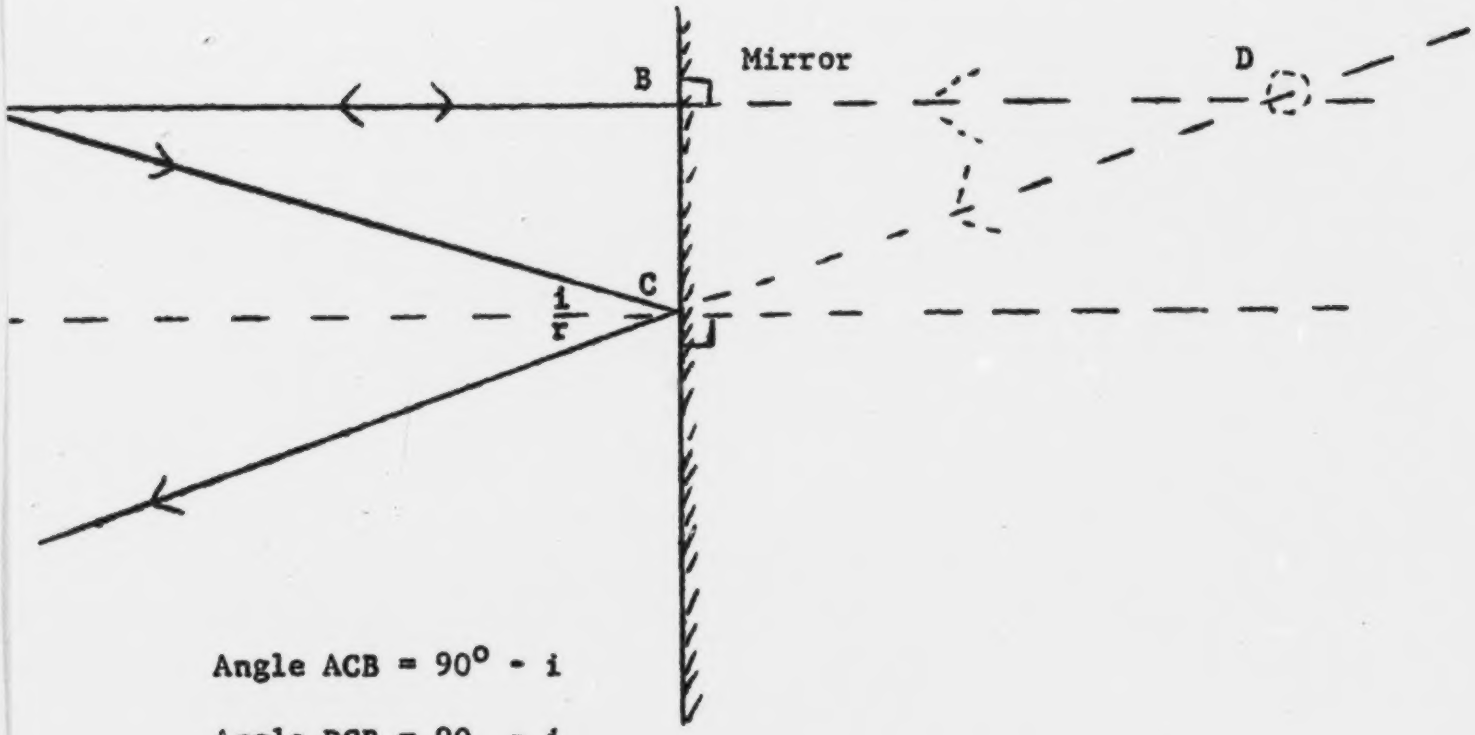
Figure 1.


Normal
Reflected Ray
Incident Ray
r
i
Reflecting Surface

We can use these laws to find the apparent locations of images formed by mirrors, since we can project the rays which come off the mirror back to their apparent origin.

Table 6--Continued

Figure 2.



Angle ACB = $90^{\circ} - i$

Angle DCB = $90 - i$

1. So angle ACB = angle DCB

2. Angle ABC = angle DBC

3. BC is common to both triangle BCA and triangle BCD,

so triangle BCA = traingle BCD

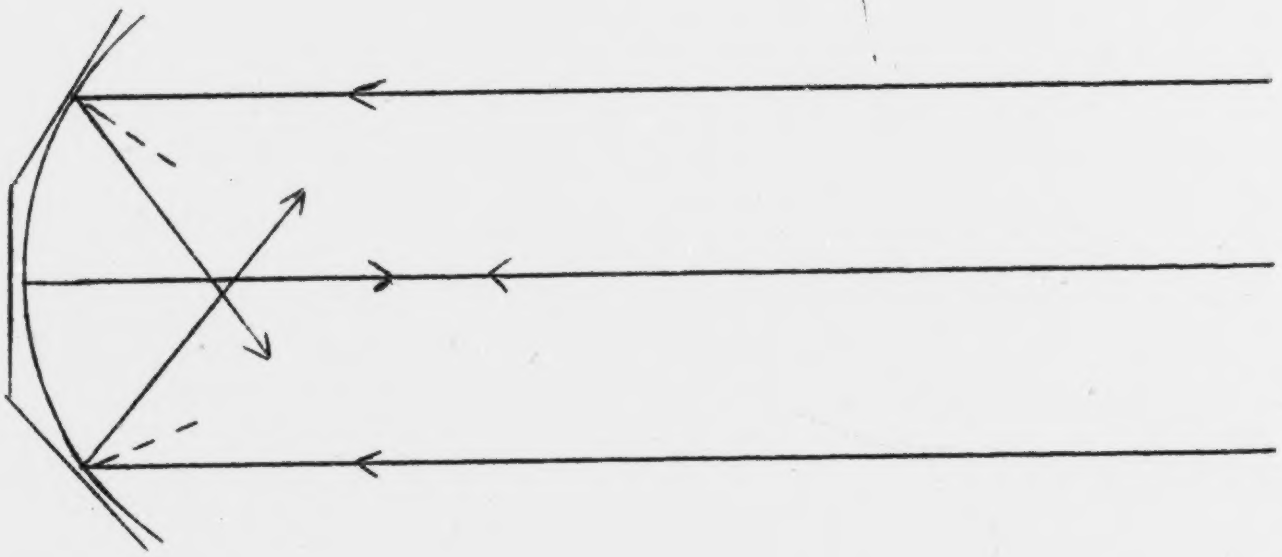
since 2 angles and 1 side are the same for both.

Thus, the image at D is as far behind the mirror as the object at A is in front of it.

Virtual image = no light rays actually pass through it.

Table 6--Continued

Figure 3.



Real image: an image located by actual light rays instead of extensions of actual light rays.

Refraction: bending of the path of light when it travels from one medium to another.

The angle of refraction, r, is measured between the normal to the interface and the refracted ray.

Table 6--Continued

Figure 4.

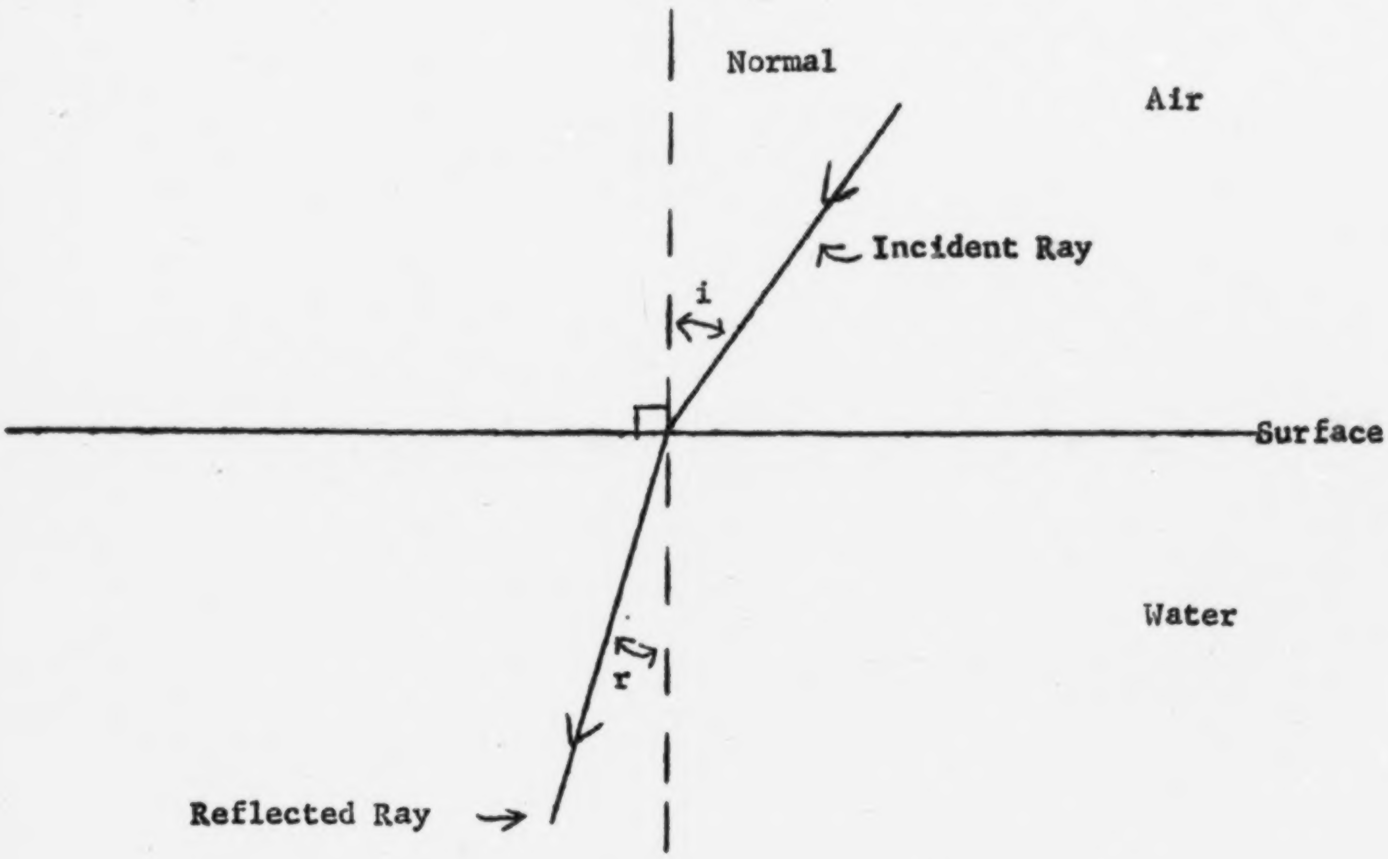

Normal
Air
Incident Ray
i
Surface
Water
r
Reflected Ray

Figure 5.

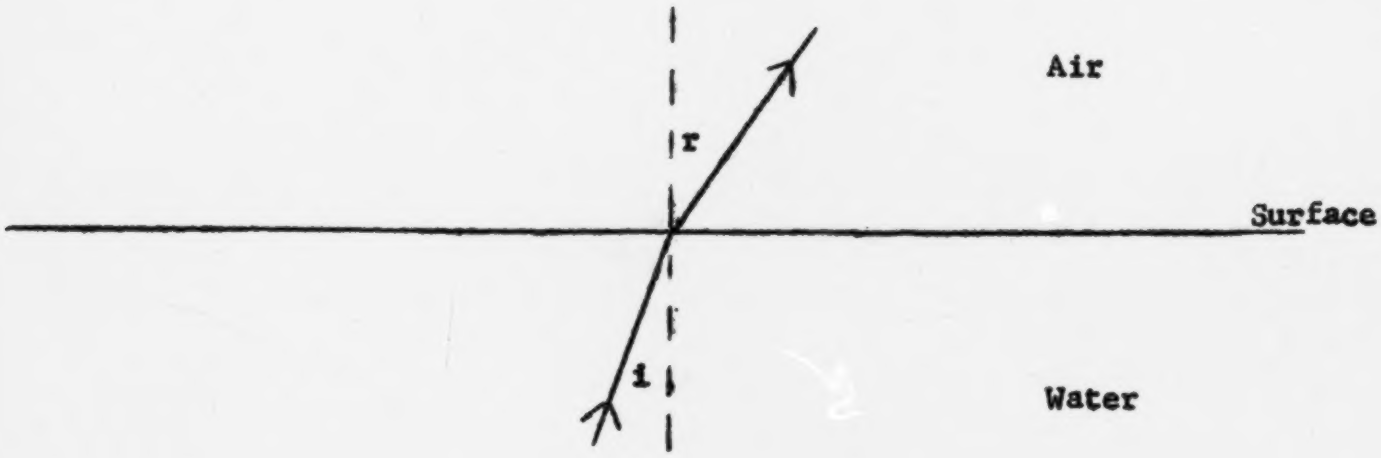
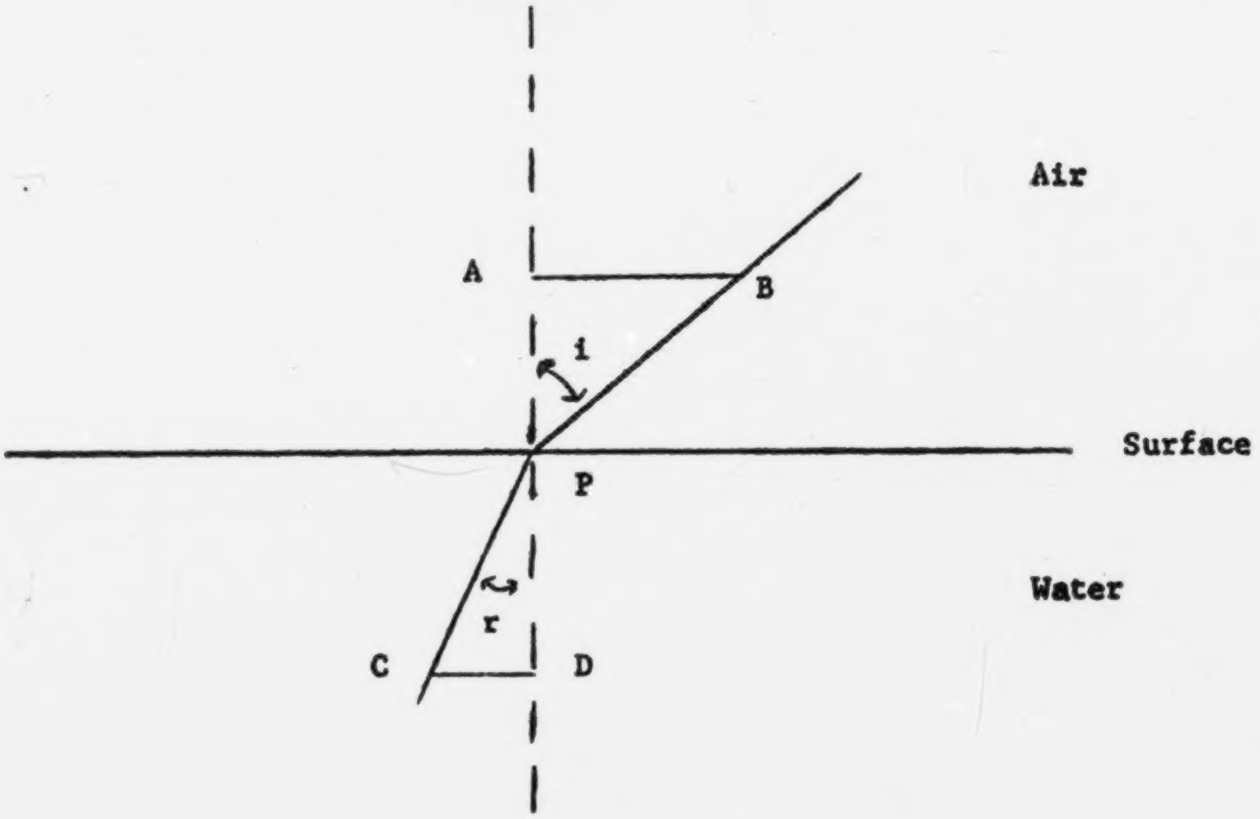

Air
r
Surface
i
Water

Table 6-- Continued

Figure 6


Air
A
B
i
Surface
P
Water
r
C
D

$$\frac{AB}{PB} \Big/ \frac{CD}{PD} = \text{n, a constant}$$

$$\frac{AB}{PB} = \text{Sin } i$$

$$\frac{CD}{PD} = \text{Sin } r$$

So $$\frac{\text{Sin } i}{\text{Sin } r} = n \quad \text{(Snell's Law)}$$

Table 7

Description of Film Loop No. 24

Refraction and Reflection of Light

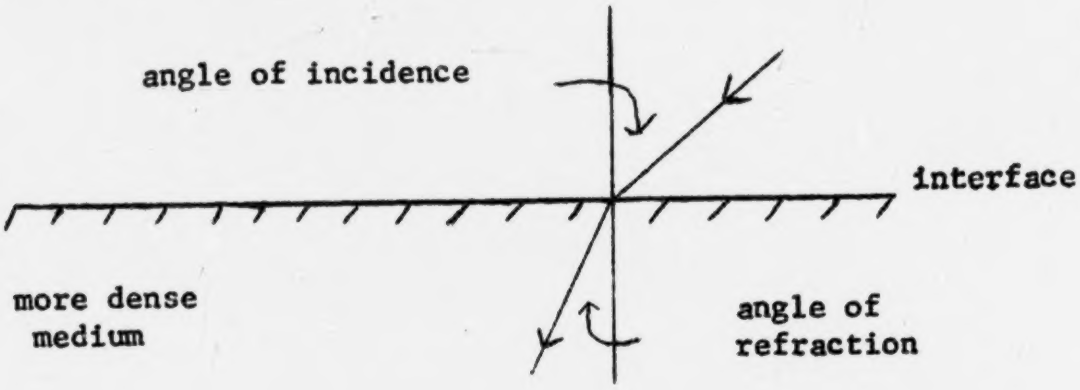
OBJECTIVE

To illustrate the refraction and the reflection of light.

DEMONSTRATION PROCEDURE

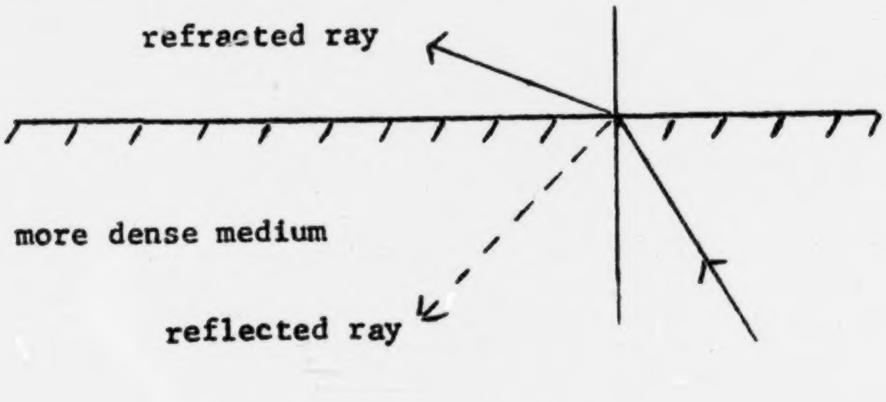
1. Observations are to be made on the angles of refraction (light enters from above) as the angle of incidence is continuously varied from approximately zero to forty-five degrees.

It is observed that there is a definite bending of the ray at the interface between the two media and the angle of refraction is less than the angle of incidence.


angle of incidence
interface
more dense medium
angle of refraction

2. Observations are made on the angle of refraction (light proceeds from below from a more dense medium into air) as the angle of incidence is continuously varied from zero to forty-five degrees.

At about forty-five degrees, the refracted ray reaches ninety degrees and is quite colored. As the incident angle is increased, there is no refracted ray--only a reflected ray - and we have total internal reflection.


refracted ray
more dense medium
reflected ray

The films were prepared by the Physical Science Study Committee (PSSC) of Educational Services Incorporated. The teacher's guide to the films describes their contents as follows:

> The films do not glitter. There is no background music, and there are no elaborate stage settings. They present a number of real scientists, speaking in their individual ways to students, directing their attention to key points. The films are planned with attention to the general aims of the course and to the development of related ideas. They usually treat the course topics in more depth and discuss the topics from a different experimental approach. Generally, the films present experiments that most schools are not equipped to do. It has been demonstrated that when properly used they make it possible for the teacher to increase his effectiveness and efficiency in teaching the PSSC physics program. Indeed, the non-PSSC teacher will also find many of these films useful to his program.

Table 8 presents the specific description of the film on optics.

The logistics of showing twenty films *m* times to *n* individual students with two conventional 16-mm. projectors was a major challenge within the course. This could prove to be a significant problem in the context of individualized instruction. Should the CAI physics course be taught on an operational basis, this problem could be solved by the use of a number of automatic self-threading projectors. Special earphones could be used so that many projectors showing different films could be used in the same room.

Summary. This section has described the course flow of a typical lesson in the CAI course, and has compared this with the conventional course. The role of the textbook, instructional terminal, audio tapes, film loops and 16-mm. films was described. Detailed examples of lesson topics, lesson flow outlines, and film titles were also provided.

Table 8

PSSC Film 201

Introduction to Optics
Lesson 6

The aim of this film is to introduce the student to some of the more important aspects of the behavior of light; to those experimental observations which support the idea that light propagates in straight lines, and to various ways in which the direction of propagation may be changed.

Summary

The sharpness of the shadow of an opaque object illuminated by a small source is presented as the basic evidence for the rectinlinear propagation of light. The fuzziness of shadows cast by objects illuminated by large light sources is demonstrated and explained. It is then shown that even with a very small source, close examination of the shadow - especially near the edges - discloses the phenomenon of diffraction. Thus, the statement that light travels in straight lines is one of limited validity.

The change of direction of propagation of light is demonstrated by scattering from smoke particles, by specular reflection, and by refraction. Reflection from a thin soap film is shown to demonstrate interference - not referred to by name - and the phenomenon of total internal reflection is also shown and discussed.

V

CAI PHYSICS PROBLEM EXERCISES

A. Introduction

When considering the most efficient method of developing an autonomous computer-based course which was to be consistent with the structure of an ongoing instructional program, the decision was made to first develop those parts of the physics course which could contribute to the understanding of entry performance levels of the students and appropriate behavioral objectives. The physics problem exercise involved the development and field evaluation of physics review material, problem exercise, and prototype exam questions to complement the existing lecture series. The review sections represented a parsimonious statement of the central propositions found within the four major content areas of the introductory physics course. In the conventional course, the students are required to identify important definitions and relational statements. The problem sections of the CAI physics problem exercises were programed in a form analogous to the problems given as homework assignments. The test questions were essentially parallel test items to those found in the within-term and final examinations in the course.

The content of the problem exercise can be divided into the four major conceptual areas that form natural segments within the conventional course. A one-hour class examination was given following each of these four segments. The four major areas of the course are as follows: (1) Scientific Theory and Measurement, which includes the topics of scientific theory, measurement, scientific notation, vector notation, and scaling; (2) Wave and Particle Theory, which includes topics in wave particle theory as developed within the context of optics concepts; (3) Classical Mechanics, which includes the concepts of force, mass, acceleration, momentum, energy and work; and (4) Electromagnetic Theory in Modern Physics, which includes the topics of electricity, electromagnetic theory, atomic theory and quantum mechanics.

During the fall quarter of 1966, the development of review, homework, and test items to be presented by CAI was completed. This early preparation of physics drill materials provided an early involvement with students who were enrolled in the introductory physics course, P107. In order to remain consistent with FSU policy on class hour requirements, the CAI activities were field tested on a voluntary basis; that is, the students from the course only participated if they felt that the CAI activities represented a valid contribution to their performance in the course. In order to allow for the greatest possible flexibility for the students, the physics drill materials were programed in concept blocks in such a manner that the students could self-select those blocks which they desired to study via CAI. There was no requirement that any given student had to work through all of the CAI practice exercises.

The basic strategy in developing these CAI physics problem exercises was to establish a baseline by which we could judge whether future curricular developments were really improvements. Consequently, these review and problem sessions provided naturalistic, baseline data by which to judge whether the total course, which included the complete presentations of all the topics, was equivalent or superior to conventional instruction.

B. Operational Procedures

As the CAI material became available during the fall quarter of 1966, students enrolled in the conventional course were offered the opportunity to participate in the field testing. The scheduling procedures were initiated by a presentation to each of the large class sessions about the nature and purpose of the CAI materials. During this and subsequent visits, questions which the students had about the activities were answered. Most of the questions consisted of queries of how the students' answers would be evaluated and how correctional procedures for wrong answers would be indicated.

Since the CAI materials had only limited pretesting, it was anticipated that a number of questions would occur when the students were actually at the CAI terminals. Therefore, staff members served as proctors. A proctor's guide was developed in order to have a clear understanding of their function, especially in relation to their interaction with the students. In essence, the proctor's guide gave a set of procedures by which questions could be handled. In addition, the proctors were given correct answers to all problems as well as references to the textbook so that all conceptual questions could be answered.

As each physics student arrived at the CAI Center, he was assigned to a 1440 typewriter terminal and given a student instructional booklet. The booklet included a brief introduction to the CAI terminal, helpful hints, and a conceptual review of the materials which were available. Presenting materials in this form saved a great deal of computer-originated "typing time" at the terminal. In some cases, information about actual problems, as in the Vector section, were presented. Thus, the booklet saved on additional presentation time and gave reminders as to the notational system found in the CAI course material. A sample from the booklet on Force Vectors is shown in Table. 9.

C. Results, Fall 1966

As noted above, the primary concern of the physics project staff during the early phase of the project was the preparation of the course material in order that students would have sufficient access to the CAI presentations. As indicated in Table 10, one can note two important consequences of this initial field testing. First, the interest of the students progressively increased during the fall trimester of 1966. During the first CAI session which covered the first major area of the course, only a small portion of the enrolled students voluntarily participated in the CAI practice exercises. There were

Table 9

Sample from Instructional Booklet which accompanied CAI Practice Exercises on Force Vectors

Force vector - the force required to lift a ten pound box from the floor may be represented by a force vector having a length proportional to ten pounds and pointed up from the floor. See Figure 2 below.

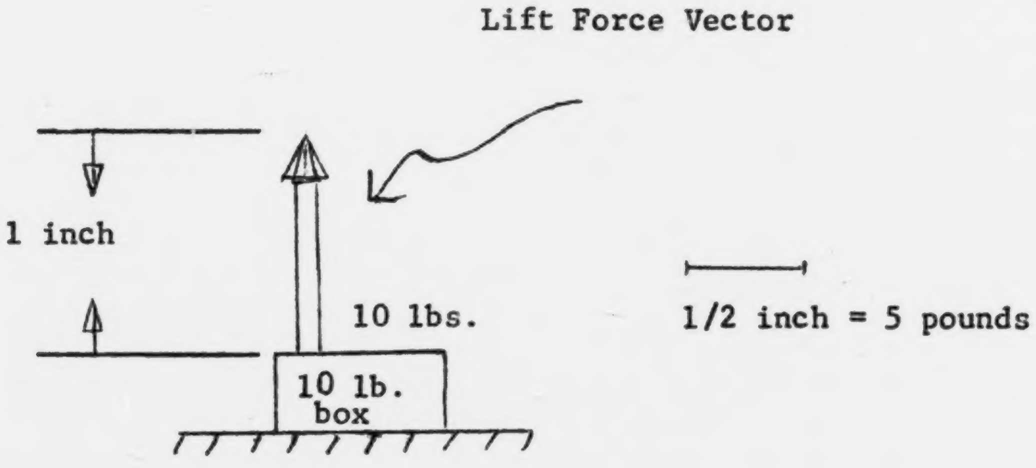


Figure 2: A Force Vector

The problems you will now see require that you construct some vectors. For this reason, we asked you to bring a ruler. If you do not have one, call for the proctor and he will loan you one of ours.

In addition to this booklet, we have also given you some graph paper. You will find this paper very useful in constructing your vectors.

To be sure we work in the same directions, always consider

1. the top of the graph paper, NORTH
2. the right-hand edge, EAST
3. the left-hand edge, WEST
4. and, the bottom edge of the paper, SOUTH

Table 10

Mean Proportion of Initial Correct Responses to CAI Problems for Specific Concepts in Physics

Session	Concept Topic	Mean Proportion Correct	N
I	Scientific Notation	.89	49
	Scaling	.82	50
	Vectors	.74	49
II	Force	.88	131
	Momentum	.85	135
	Work	.63	146
	Energy	.58	143
III	Electromagnetism	.43	256
	Motion	.48	249
	Optics	.67	211
	Modern Physics	.76	236
IV	Final Examination	.93	276

approximately 580 students enrolled in the course; only 9 percent chose to participate during session one. However,25 percent participated during session II, 44 percent participated during session III, and 48 percent participated during the final session. It should be noted that the CAI Center could, at that time, only accommodate approximately 280 students under full-day sessions for the ten days prior to the examination. Consequently, the final session represented full utilization of the available terminal equipment. This growing interest in voluntary participation was interpreted as a first order approximation towards validating the usefulness of the CAI instructional approach.

Secondly, Table 10 indicates that the students performed differentially on the various concept topics. The low performance in topic areas such as vectors, work, energy, electromagnetism, etc., was undoubtedly due to the high representation of quantitatively-ordiented problems in these sections. In essence, the students in the introductory physics course find it very difficult to work quantitatively-oriented problems. On the other hand, it should be noted that the students did perform at a remarkably high level on the section called the final exam. All of the above interpretations, however, must be qualified since these findings are based upon evidence from a voluntary population. Each topic statistic, however, was interpreted as indicating possible areas with which students need more extensive instruction and practice.

As was noted in the description of the course structure, students were given the options of which topics, and in what sequence, they wished to review. Figure 2 shows a schematic tree diagram of the sequence in which 46 students in the first CAI session selected topic areas. It can be noted that the students did vary considerably in the order in which they selected their topics for study.

It appeared that students found it useful to have a certain amount of self-selectional initiative in going through the physics practice exercise material. The results were encouraging in that there was a remarkably large voluntary participation by students enrolled in the conventional course and the commentaries from both the students and course instructors were highly favorable.

D. Winter 1967 Development

During the development of the CAI review problems, there was speculation whether a more general set of problem-solving skills could be taught to the voluntary students who were participating at the CAI Center. A set of learning materials were developed which dealt with problem-solving strategies in physics. These materials consisted primarily of instruction in the nature and balancing of units within equations. In addition, the students were provided with some insight into the solution of fairly quantitative types of problems and some actual exercises in performing simple algebraic operations on simple equations. As students scheduled for practice exercise sessions in the CAI Center, they were randomly assigned

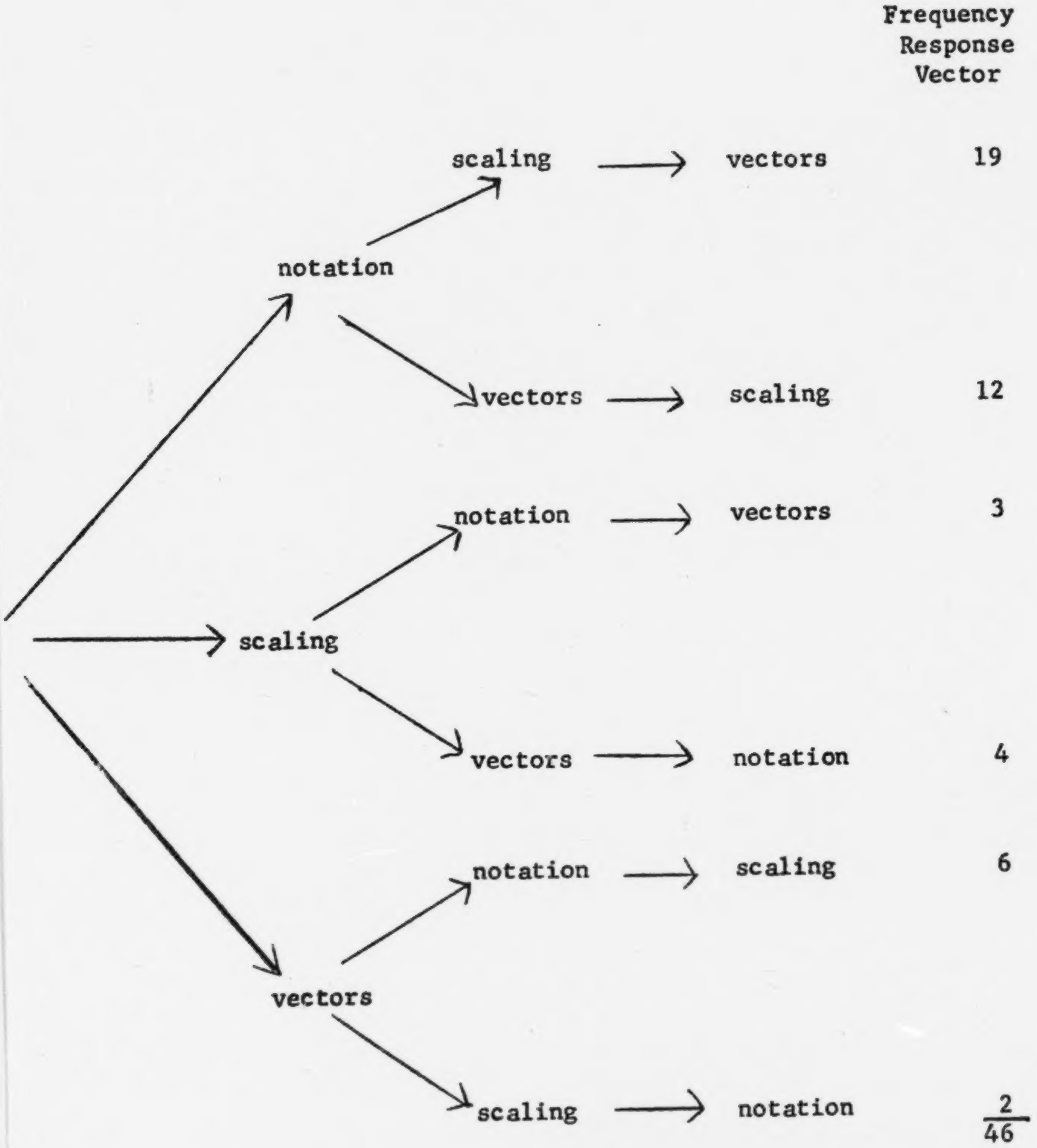

Frequency Response Vector
scaling
vectors
19
notation
vectors
scaling
12
notation
vectors
3
scaling
vectors
notation
4
notation
scaling
6
vectors
scaling
notation
2
46

FIGURE 2

Sequential Selection Order of Review Topics for Those Students Completing all Three Topics in Session I.

either into a special treatment group receiving the problem-solving strategy materials, or a group receiving the standard CAI practice exercises.

E. Results - Winter 1967

Table 11 indicates the outcome of the comparisons in terms of the performance of these two groups on a series of topics found within the early section of the course. It can be seen that there was no apparent difference between the two groups. The attempt at developing these problem strategy materials, consequently, has been judged to be less than adequate. It is suspected that the section was too abstract and too general; it would need to be tied down to specific concepts within physics with recurrent reminders about the various problem-solving strategies if it was to become effective.

These two CAI groups were combined for a comparison of the performance of the students who participated in the CAI practice exercises with those students from the conventional course who did not choose to do so. The reader should be forewarned that a serious problem of selectivity is represented in this data; that is, only those students who voluntarily wished to participate in the CAI presentations did so. One would naturally speculate that those students more anxious to perform well in the course would be prone to volunteer for the CAI instructional help. Table 12 presents the mean performance of the two groups on thefour one-hour examinations in the course. The examinations were presented in the conventional paper and pebcil format and represented a direct comparison of those students who had participated in CAI and those students who had not. It can be seen that the CAI participating students performed approximately 10 percent better on all of the four one-hour exams. The results are highly consistent in indicating that the CAI group was superior to the non-CAI group. The problem of obtaining more conclusive evidence remained for the fall term of 1967 when the full multi-media computer course was field tested.

Table 13 presents the performance level of the CAI students on each of the concepts offered during the Winter, 1967. Within each one of these concepts there are subtopics by which the data was organized; but for the sake of brevity, the data has been pooled together under each major concept. By looking at Table 11 and Table 13, one can view the amount of selection and the performance on various concepts during the second term of the 1966-67 academic year. The performance on the topic proceeds from a high level on those introductory topics such as scientific notation and order of magnitude to a fairly low level dealing with such concepts as electricity and modern physics. One can only speculate that the pace of the conventional course or the conceptual development by the students is insufficient to maintain a high learning level throughout the course. In a physics course, the increasing complexity of the concepts and their building one on another appears to inhibit the students' learning performance in the later portion of the course. (It should be noted that it is not likely that this trend is simply a result of decreasingly effective

Table 11

Comparison of two groups of CAI participating students--
a problem-solving group and a standard group
Winter, 1967

Comparison Item	Problem-Solving			Conventional		
	N	M	SD	N	M	SD
CAI instructional time in hours	67	1.65	.63	64	1.86	.69
Scientific notation	66	.69	.26	54	.88	.21
Orders of magnitude	58	.61	.14	58	.63	.17
Scientific calculations	55	.70	.21	51	.69	.23
Functional relationships	53	.89	.14	52	.79	.13
Theory of scale models	55	.52	.19	51	.51	.17
Measuring short distances	53	.69	.16	56	.60	.20
Change of scale	53	.51	.21	54	.45	.19
Crystals	56	.50	.19	51	.41	.14
Gases, atoms, & molecules	50	.72	.13	49	.65	.25
Total correct on CAI	67	.61	.12	64	.58	.11
Score on first hour exam	67	.81	.11	64	.85	.10

Table 12

Mean scores for CAI participating students and conventional students on four hourly course examinations

Examination	CAI Group			Conventional Group		
	N	M	SD	N	M	SD
First hour exam	131	.83	.10	357	.76	.03
Second hour exam	177	.78	.10	349	.69	.04
Third hour exam	195	.77	.10	341	.70	.03
Fourth hour exam	184	.64	.12	329	.53	.06

Table 13

Mean proportion correct values on various physics topics presented via CAI problem exercises

Winter, 1967

Topic	N	M	SD
Refraction	173	.57	.18
Reflection	174	.69	.25
Light particles	173	.66	.32
Wave behavior	174	.65	.23
Acceleration	199	.57	.28
Mass	198	.41	.27
Momentum	197	.61	.25
Energy	195	.39	.24
Work	194	.33	.24
Force	191	.52	.27
Electrons	185	.31	.22
Electric currents	179	.37	.26
Magnetism	181	.54	.21
Induction	176	.35	.23
Atomic structure	181	.66	.21
Modern physics	173	.43	.18

lecture presentations; the lecturer has been recognized at FSU as being most outstanding and appropriate awards have been given for excellence of instruction.

F. Summary

The field studies of the CAI problem exercises accomplished a number of objectives. Most importantly, they provided baseline data with which future curriculum revisions could be compared. They demonstrated the potential positive effect of CAI. They provided the corpus of problem exercises that were revised for inclusion in the full autonomous course. They helped identify those particular learning problems that the full course would have to face.

The experience with the FSU students indicated the feasibility of a computer-based course. Insights were gained into the need for and requirements of the proctoring role. Therefore, we recommend to other CAI R and D projects the merits of approximating a course via this strategy. Moreover, the positive outcomes suggest the desirability of having this kind of CAI application available for any number of collegiate courses.

VI

Field Study: Fall, 1967

A. Introduction

The first full field evaluation posed a number of problems that required quick and adequate solution. First, the granting of credit for the course and the selecting of students required administrative approval. The techniques for gaining institutional support and approval will be discussed in conjuntion with student selection procedures. Secondly, the completion of various media presentations including concept films, as well as course outlines and CAI coding, required many last minute adjustments since the preparation schedule failed to reflect many unanticipated delays (i.e., late delivery of the IBM 1500 CAI system, inaccurate film reproductions, etc.) Most importantly, the underestimate of the need for media duplicates to resolve queuing problems imposed some minor scheduling delays (some students had to wait up to 30 minutes for certain films and audiotapes). Given the commitment to execute the entire course of instruction, the project staff solved each momentary problem in a manner that insured completion.

B. Student Selection

The university administration requested that all students selected for the CAI course be given the opportunity to voluntarily elect to participate. Since the majority of freshmen at FSU preregister in the summer for the fall term, we selected a pool of 100 students who were both pre-enrolled for Physics 107 and were not participating in other freshman research projects. These students were contacted by mail; 67% responded favorably, 6% unfavorably, and 27% failed to respond. Thirty of the favorable respondents were randomly selected and notified. Due to course changes and a misunderstanding concerning the one-credit physics laboratory course, seven of the students dropped from the sample. Since classes had met for two sessions, it was decided not to replace these seven dropouts, although there were numerous volunteers available. There is no reason to believe that the sample of 23 students was biased or nonrepresentative of the students enrolled in Physics 107.

The comparison group of students from the conventional course was selected by matching sex and aptitude entrance scores on the Florida Twelfth Grade Examination of these students with those of each CAI participant. Within these matches, randomly sampling procedures were used to match one student from the conventional course with each CAI student. Another comparison group was formed by those students from the conventional course who voluntarily participated only in the CAI practice exercises.

C. Course Progress

After a brief introductory and explanatory session on the first class day of the fall term, each CAI student self-scheduled his own sessions on the course materials. The midterm examination was given after the completion of both Lesson 13 and the CAI review exercises on the 1440 CAI-typewriter system. The review session was identical to that offered to the conventional students who took only the CAI problem exercises. Since there were two review sessions and two examinations, the course consisted of 33 sessions. Figure 3 presents the cumulative lesson progress curves for the fastest and slowest student. These curves are typical in that each student tended to cluster his instruction within certain weeks. Table 14 illustrates this clustering phenomenon in that 62 percent of the lessons were taken in multiple-lesson sessions. There were marked drops in attendance during the midterm examination period and during certain big, extracurricular events such as key football games. The students acknowledged, during later interviews, that they utilized their control of the physics instructional schedule to optimize their participation in other collegiate activities and their performance of other academic requirements. The students considered this scheduling flexibility to be one of the key benefits of the CAI course.

The mean length of time required for completion of the course was 10.9 weeks in the eleven-week term. When students are allowed to self-schedule, the course completion outcome tends to contradict the common claim that CAI courses will dramatically reduce the length of academic terms. However, the mean time required to complete the 29 lessons was 23.8 hours of instruction. This represents a 17 percent savings in instructional time. Considering the fixed durations of the films and audio presentations plus the opportunity for repetition of difficult material, this time savings indicates a significant savings in instructional time. It is worth noting that only 3 percent of the informational presentations were voluntarily repeated by the students, while approximately 45 percent of the CAI interactive responses were repetitive attempts to seek a correct answer. Thus, the prediction of an instructional time savings for CAI was substantiated in this first field evaluation.

D. Course Procedures

In reviewing the operational procedures, it was noted that 95 percent of the students' questions related to the location and operation of the non-computer, audio-visual equipment. Without a doubt, the 16-mm. sound films proved to be the biggest scheduling and operational problem. While equipment failures were minimized by having extra equipment, the effectiveness of operation could only be maintained by having knowledgeable technicians available to set up the films. It was also found that the introductory and explanatory materials for the 8-mm. concept films were ambiguous at times. Student comments and learning performance were both lower and more variable for films in general. While the operational aspects of the course required constant attention and service, they were successful in that no student sessions had to be cancelled.

Figure 3

Cumulative Progress Curves of Lesson
Completion During Eleven Weeks
of the Course

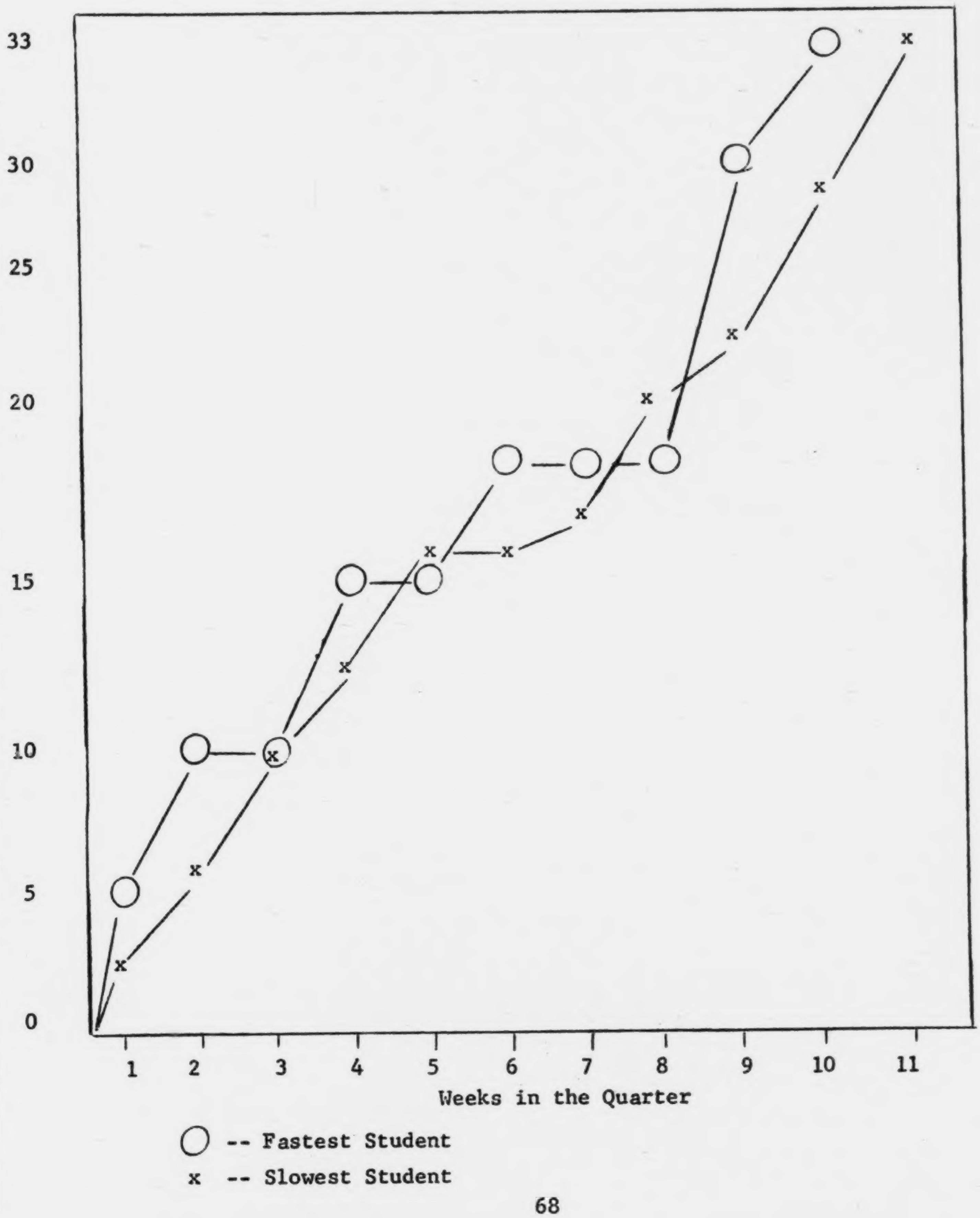


Table 14

Distribution of Lessons Completed per Attendance Session

	Number of Lessons Completed Per Session						
	1	2	3	4	5	6	7
Frequency	251	114	40	10	3	1	1
Percentage of Lessons	.38	.34	.18	.06	.02	.01	.01

E. Performance Results

The learning outcomes as reflected in the final grade assignments for the three groups indicate a marked superiority for the autonomous CAI students as illustrated in Table 15. A correlated "t" test on the sum of the midterm and final exam scores indicated that the autonomous CAI group was statistically superior to the other two groups, but the difference between the partial CAI and conventional students was not significant. The high proportion of "A" grades in the autonomous CAI group represents one of the few instances in which the upper half of a score distribution shifted under CAI treatment. It is much more frequently found that the lower half of the grade distribution is truncated due to a CAI treatment. As other analyses will support, this superior examination performance may be attributed to the impact of the CAI conceptual interaction sections which are found within each of the lessons.

The comparison of performance on various topics in the lesson materials, with the prior baseline data collected during the preparation of the course, provides some insight into the impact of the autonomous CAI lesson material. As indicated in Table 16, the CAI lesson material was categorized into three types of instruction: 1) assessment of textbook reading, 2) assessment of film presentations, and 3) conceptual assessment via problem presentations. For simplification purposes, the lessons were grouped into the five main concept domains of scientific measurement, optics and light, force and energy, electricity, and modern atomic physics. The last column in Table 16 indicates the baseline physics exercise results which were collected during the developmental phases of the project. As the baseline results indicate, the conventional course performance is marked by a gradual decrease in achievement while the conceptual complexity of the topics is judged to be increasing. The performance on the film presentations also indicates a gradual decrement in mastery. On the other hand, the performance on the textbook assessment and the conceptual problem exercises remains markedly constant. These stable performance levels may be interpreted as indicating a clearer reflection of the learning performance that resulted in the superior examination scores by the autonomous CAI group.

Through the use of multiple regression techniques, each of the category lesson scores (i.e., scores on textbooks, scores on films, and scores on conceptual exercises) for the first half of the course were regressed onto the midterm examination score, and scores from the second half of the course were regressed onto the final examination score. These results are presented in Table 17. The CAI conceptual problem scores yield significantly higher multiple correlations with the examination scores. These higher associated relationships plus the stable performance levels for the CAI conceptual problems are indicative of the positive impact of the computer interactions on the examination performance. These performance results seem to demonstrate that a CAI approach can eventuate in superior conceptual mastery in physics.

Before this conclusion appears to be too sweeping, it must be noted that performance on some of the CAI lessons, as for example the topic of electrical induction, was far from satisfactory (the mean correct response proportion was approximately .40). The performance on the film materials

Table 15

Frequency Distribution of Grades for the Three Instructional Groups

Conditions	Grades A	 B	 C	 D	Mean Grade
Total CAI	11	6	6	0	3.22
Partial CAI	6	7	10	0	2.83
Conventional	4	5	13	1	2.52

Table 16

Mean Correct Proportions on First Responses to Different Lesson Material Categories by Conceptual Topics

Concepts	Textbook	Films	Conception Exercises	Baseline*
Scientific Measure	.698	.611	.586	.591
Optics and Light	.733	.675	.673	.578
Force and Energy	.706	.547	.666	.483
Electricity	.703	.476	.653	.391
Modern Physics	.703	.486	.605	.412

*Data collected on prior student groups.

Table 17

Multiple Correlations of Lesson Categories with Examination Outcomes

	Mid-Term Examination	Final Examination
Textbook	.605	.694
Films	.587	.445
Conceptual Exercises	.870	.901

indicated a need for extensive revisions in this aspect of the course. But, if viewed as a first field trial, the learning performance results do support the conception that a computer-based multi-media course that attempts to individualize instruction can eventuate in superior concept mastery.

F. Attitudinal Results

The attitudinal responses of the students to the Brown Scale on Attitudes Toward Computer-Assisted Instruction indicated a moderately positive reaction to the course. A summary of the questionnaire findings indicates that the students 1) were aware of the constrained dialogue of the CAI materials, 2) tended to guess at times, and 3) had a desire for even more individualization. All of the participants considered the CAI course to be preferable to their corresponding conventional courses.

Personal interviews revealed two especially important reactions. First, all of the participants indicated a personal feeling of greater concept mastery in comparison with their peers. For example, the participants claimed to be better explainers of homework problems in comparison with dormmates who attended the conventional course. The second reaction relates to the man-machine interface issue. All of the participants indicated a preference for the automated typewriter interaction in comparison with the CRT-light pen interaction. While many factors may underlie this unanimous reaction (the flexibility and meaningfulness of the typewriter-presented review material, the opportunity to obtain a personal copy of the problem exercises, etc.), this finding should be investigated in light of the higher costs associated with CRT terminal equipment.

G. Manpower--Cost Factors

Cost effectiveness analysis in educational technology is fraught with categorization and estimation problems. A foremost consideration for CAI projects is the clear differentiation, if possible, between course development costs and the operational costs of instruction. Table 18 presents a simplistic breakdown of the costs associated with the college physics project. Most category items are self-explanatory. The most noticeable discrepancy is the modest cost for actual course operation and the high costs for computer systems programming. To date, most CAI project reports have omitted the reporting of the high costs involved in implementing a manufacturer's computer system to the status of acceptable operations. While most of the incurred costs for the FSU project may appear substantial in nature, the CAI systems cost represents a one-time investment required to organize and manipulate the learning data so that project goals, especially those of course revision, can be accomplished. After the developmental costs are amortized, the operation of a CAI autonomous course begins to compare favorably with that of conventional courses.

The question of cost effectiveness requires the assessment of the worth of the improved learning outcomes reported above. While one can attempt to scale these utilities, it is left with the reader to assign value quantities to the unanticipated high proportion of superior grades.

Table 18

Cost Estimates of Developmental and Operational Activities Expensed By the FSU Physics Project Through December 31, 1967

	Category	Man Years of Effort	Cost
I.	Physics Course Preparation		
	Physics Writers	2.0	$ 20,000
	Physics Faculty Consulting	1.0	20,000
	Films and Audio Preparation	.5	4,000
	CAI Coding	1.0	6,000
	Behavioral Scientist	1.0	14,000
			$ 64,000
II.	Computer Systems Development		
	Data Management System	3.0	$ 30,000
	Data Analysis Programs	2.0	16,000
	Data Analysis Operations	1.0	6,000
			$ 52,000
III.	Administration and Services		
	Administrator	.5	$ 7,500
	Secretaries	2.0	10,000
			$ 17,500
IV.	CAI Course Operations		
	Proctors		$ 2,500
	Physics Tutors		1,200
	Computer Operator and Technician		3,000
			$ 6,700
			$139,200

Quality education has amorphous characteristics that pose serious obstacles to definitive cost analyses.

H. Summary

In considering the empirical outcomes from this first field test, the substantial, multiple-correlation relationship between the CAI conceptual exercise material and the examination scores that lead to the grade outcomes was most encouraging. A class of linear models were investigated that will provide each student with realistic probability statements about course mastery. If the values become too low, additional practice on a concept will undoubtedly be prescribed. Otherwise, the student will be allowed to self-define his level of course proficiency. The element of student self-commitment may represent a more viable pathway to optimizing the terminal outcomes for an individualized course of instruction.

VII

Spring, 1968-Field Test

Introduction

This section describes the field study of the physics course which was conducted in the Spring, 1968. The types of changes which were made in the CAI physics course materials and the type of measures which were selected for the evaluation are presented. The student sample who participated in the study, and the procedures which were utilized in implementing the study are then described. The results are summarized under four major headings, 1) Student Pacing, 2) Comparative Study of Learning Outcomes, 3) Correlational Analysis of Prior Knowledge Aptitudes, Within Course Performance, and Final Performance, and 4) Interview Information. The section concludes with a summary of the results of this second field test.

A. Preparation for Spring, 1968, Field Study

During the winter quarter, 1968, following the completion of the first study and preceding the second, a number of activities were conducted which significantly affected the Spring version of the CAI physics course. First, the entire course was reviewed in light of the student performance data, student attitudes about the course, and the logistical problems which had been encountered during the fall quarter. For example, many of the students expressed the opinion that the materials used in conjunction with the 8 mm concept films was not adequate to describe the activities depicted in the films. Therefore, all these films were reviewed and supporting documentation was greatly enhanced. Other less significant but necessary changes were made throughout the course materials.

A second task which was completed during the winter quarter was the selection of a battery of cognitive and affective tests which were to be administered to the students taking the Spring CAI physics course. The purpose of the extensive testing of the students was not only to better understand the entering abilities of the students, but also to attempt to understand the relationship of prior knowledge and entering aptitudes to success in the CAI course. It was anticipated that correlational and regression anaylses would be conducted using these variables. These types of analyses were utilized in order to indicate the relative contribution of entering capabilities and knowledge as well as the learning which actually took place during the course and on the final performance in the course. Since a major portion of the Spring field study centered around the relationship of these variables and their effect on the CAI performance, the following section describes in some detail the rationale for selecting each of the various tests.

B: Cognitive Tests

The choice of relevant tests to measure cognitive and affective factors that might be related to success in the physics course was planned as the first task for the students in the Spring Quarter presentation of the CAI physics course. The tests were selected according to the following criteria: (1) the nature of the physics content, (2) uniqueness of the CAI presentation, and (3) tests that had proven utility in measuring cognitive variables. This selection process was by necessity a partially subjective one; and testing time limitations eliminated many tests (only two, two-hour sessions could be devoted to testing). Seven tests were selected and administered to the members of the CAI experimental group during the first week of the Spring Quarter.

The cognitive ability tests which were chosen can be organized into four general areas: reading ability, listening comprehension, mathematics aptitude, and reasoning ability.

Many studies in the past have found a positive relationship between reading comprehension and success in a particular course. The CAI physics course attempted to use many modes of presentation in addition to direct reading. Reading assignments were made in the textbook, but they were also supplemented by audio presentations, films and film loops. It was hypothesized that reading ability would not be a significant factor in the CAI course. The Nelson-Denny Reading Test was included in the battery to test this hypothesis.

Students in the CAI course also spent a substantial portion of their study time listening to recorded lectures and films with sound tracts. It seemed a logical hypothesis that listening ability might be an important factor in success in the course. The four-part Brown-Carlsen Listening Comprehension Test was administed to evaluate this dimension and determine its relationship to success in the course.

Mathematical ability has always been thought to be important in success in physics. As a result, many physics courses have mathematical prerequisites. To confirm whether mathematical ability was needed for the CAI physics course, the Mathematical Aptitude Tests and the Necessary Arithmetic Test were administered.

The content of the physics course required students to synthesize concepts and relate them to solutions of problems. Therefore, it was hypothesized that if a student were weak in basic reasoning ability, he is at a disadvantage since the course is composed of numerous problems which require this ability. The Watson-Glaser Critical Thining Test, the Logical Reasoning Test, and the Ship Destination Test were administered to test this hypothesis. All of the tests utilized standarized IBM answer forms. A more complete description of these tests can be found in Appendix F.

C. Affective Tests

To investigate the relationship of affective processes with performance in the CAI physics course, it was decided to focus on anxiety as an example of the affective domain. The State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1969) was used to measure anxiety. The State-Trait Anxiety Inventory (STAI) consists of two self-report scales for measuring Trait Anxiety (A-Trait) and State Anxiety (A-State). The A-Trait scale consists of 20 statements (e.g., "I lack self-confidence") that ask the subject to report how he generally feels by rating himself on the following four-point scale: "Almost never," "Sometimes," "Often," and "Almost always." The A-State scale also consists of 20 statements (e.g., "I am worried"(that ask the subject to indicate how he feels at a particular moment in time by checking one of the following: "Not at all," "Somewhat," "Moderately so," or "Very much so." These scales are presented in Appendix I. The item selection procedures and item validation for the STAI are described in detail by Spielberger & Gorsuch (1966) and by Spielberger, Gorsuch & Lushene (1968).

It has been demonstrated that scores on the STAI A-State scale increase in response to various kinds of stress and decrease as a result of relaxation training (Spielberger, et al., 1968). Additional evidence of the construct validity of the STAI A-State scale in psychological research may be found in recent studies by Hodges (1967), Taylor, Wheeler, and Altman (1968) and O'Neil, Spielberger, and Hansen (1969). Correlations of the STAI A-State scale with other measures of A-State, such as the Zuckerman AACL Today Form, provide evidence of the concurrent validity of this scale (Spielberger, et al., 1968).

Method

A. Subjects

There were three groups of subjects used in this study; two control groups and one experimental group. The first control group consisted of subjects who attended conventional P107 lectures for the quarter and received a four-hour examination review on the IBM 1440 system. The second control group only attended conventional P107 lectures for the quarter. The experimental group took the entire P107 course via the multi-media approach. These groups were labeled 1440 review, conventional, and CAI Autonomous, respectively. The 1440 review group (N = 78) consisted of any subject from the conventional class who volunteered to take the P107 examination review on the 1440 system, while the conventional group consisted of the remainder of Ss in the conventional class (N = 141).

The CAI autonomous subjects were selected in the following manner: During registration in the spring quarter, 1968, students signing up for Physics 107 were offered the opportunity to take the CAI P107 course. The first forty volunteers within the pre-set quotas of twenty males and twenty females were accepted. There is no reason to believe that this sample was unrepresentative of the regular course population except that they were willing to participate in the CAI experiment. However, rough polling by show-of-hands in several classes indicated that about 70% of the students taking Physics 107 would have been willing to participate. Thirty-seven of the original forty students selected for the study did in fact finish the course. Of these, twenty were female and seventeen were male.

B. Procedures

The students progressed through the Spring version of the CAI physics course much as the Fall students had. Special evening sessions during the first few weeks were utilized in order to administer the battery of aptitude and personality tests to the students; a total of four hours of testing was employed. Following a brief introductory session in which they were oriented to the CAI system, the students were permitted to schedule their own sessions at the CAI Center. The only restriction which was placed upon these students was that they were required to take their midterm examination on or before the date upon which the conventional classroom received their midterm. The same type of regulation was used in relation to the final examination. In all other respects, the students essentially set their own pace for their own instruction in the CAI physics course.

Results

A. Introduction

The results of the Spring study will be presented under four major headings. The first will be a description of the pace at which the students cover the CAI physics materials. A comparison is made with the conventional class. The second section deals primarily with a comparative analysis of the midterm and final performance of the CAI and conventional classroom groups. This section includes an analysis of the within-course performance of CAI students in terms of their learning as reflected by the reading quizzes, film quizzes, lecture quizzes, and anxiety-state scale scores. The third section of the results deals primarily with the correlational analysis of the relationship among the various within-course measures and also the relationship among the various external background and aptitude measures. Each of these clusters of variables is then related to the students' final performance in the CAI course. The final correlational analysis is the utilization of all these variables in order to predict the final grade in the course. The fourth and final section of the results deals with a summary of the interview data which was obtained from the CAI students following their completion of the CAI physics course.

B. Self-pacing

One of the unique features of CAI physics course was that it provided for individual self-pacing. To determine whether, in fact, students utilized self-pacing, the distribution of lessons per session per student was calculated. The summarized data are presented in Table 19. As can be noted, only 27 percent of the occasions when the students were in the CAI Center did they complete only one lesson: 73 percent of the visits resulted in the completion of two or more lessons.

Table 19

Distribution of lessons completed per

Session for CAI students

Number of lessons completed per sitting										
1	2	3	4	5	6	7	8	9	10	11
27	38	17	9	5	0	1	2	1	0	1

It is interesting to consider the self-pacing aspect of the CAI course in more detail. Figure 4 indicates the extent to which the students in the Spring, 1968, group took advantage of the self-pacing option. Figure 3 shows the number of days after the start of the course that a given lesson was completed. The CAI data is based upon the mean of the thirty-seven students. For comparison purposes, the steady rate of the section of the conventional course is shown also. CAI students were constrained to take their midterm and final exams no later than the date on which the conventional class of students took theirs (31 days and 71 days after the start of the course, respectively). On the average, as shown in Figure 4, the CAI students finished the course eight days earlier than the conventional class students (57.4 days as compared to 66 days). The students required, therefore, approximately 12% less time in comparison to the time allocated to the conventional lecture course.

The average time of 57.4 days to complete the CAI course conceals a number of interesting facts about distributions and individual differences. For instance, only five CAI students required the full 66 days of the quarter to complete the course; the earliest "finisher" took only 44 days (See Figure 5). All students had to complete the course to take the final no later than the 71st day of the quarter.

Figure 4

Pacing of CAI and Conventional Students in P107 Course, Spring, 1968

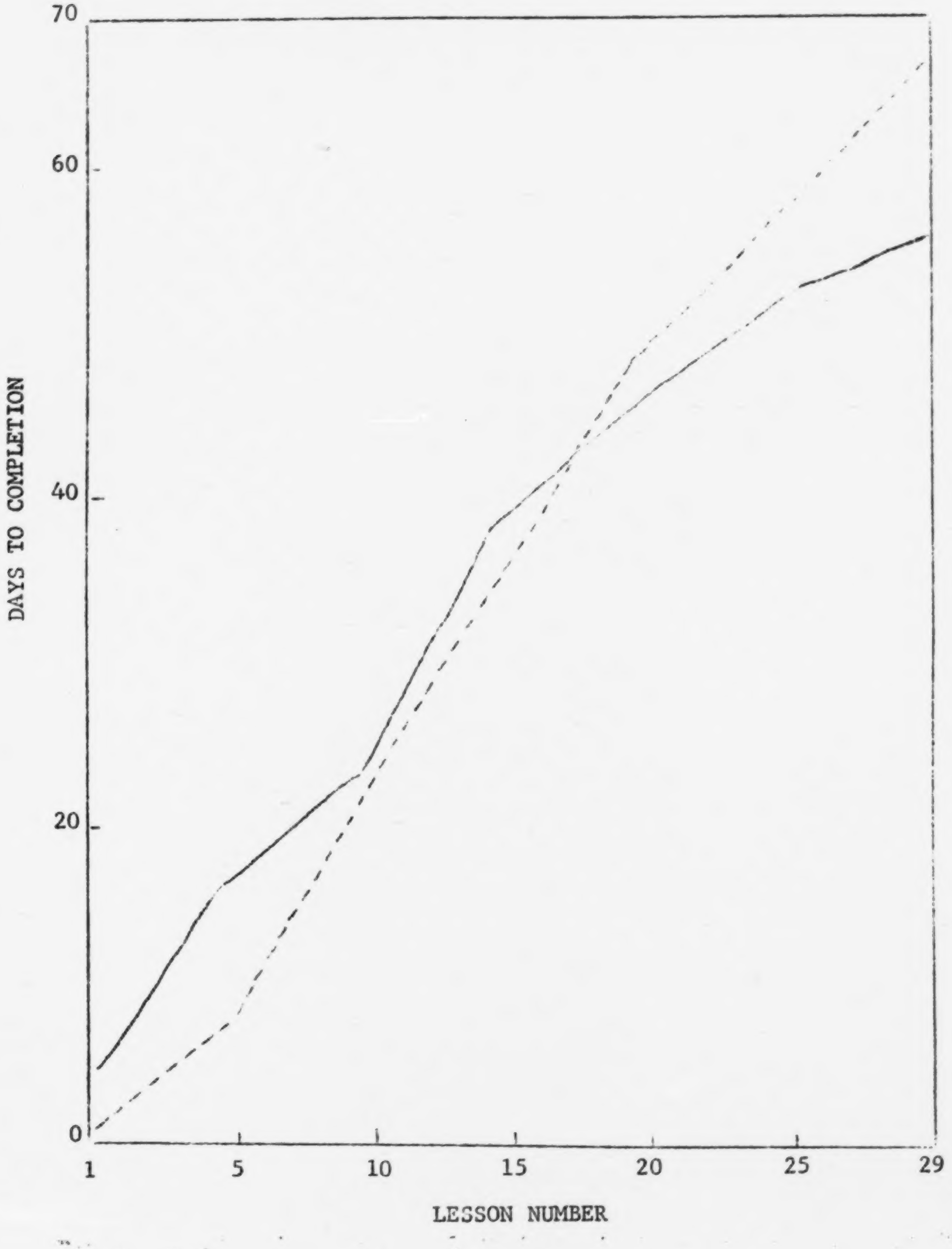
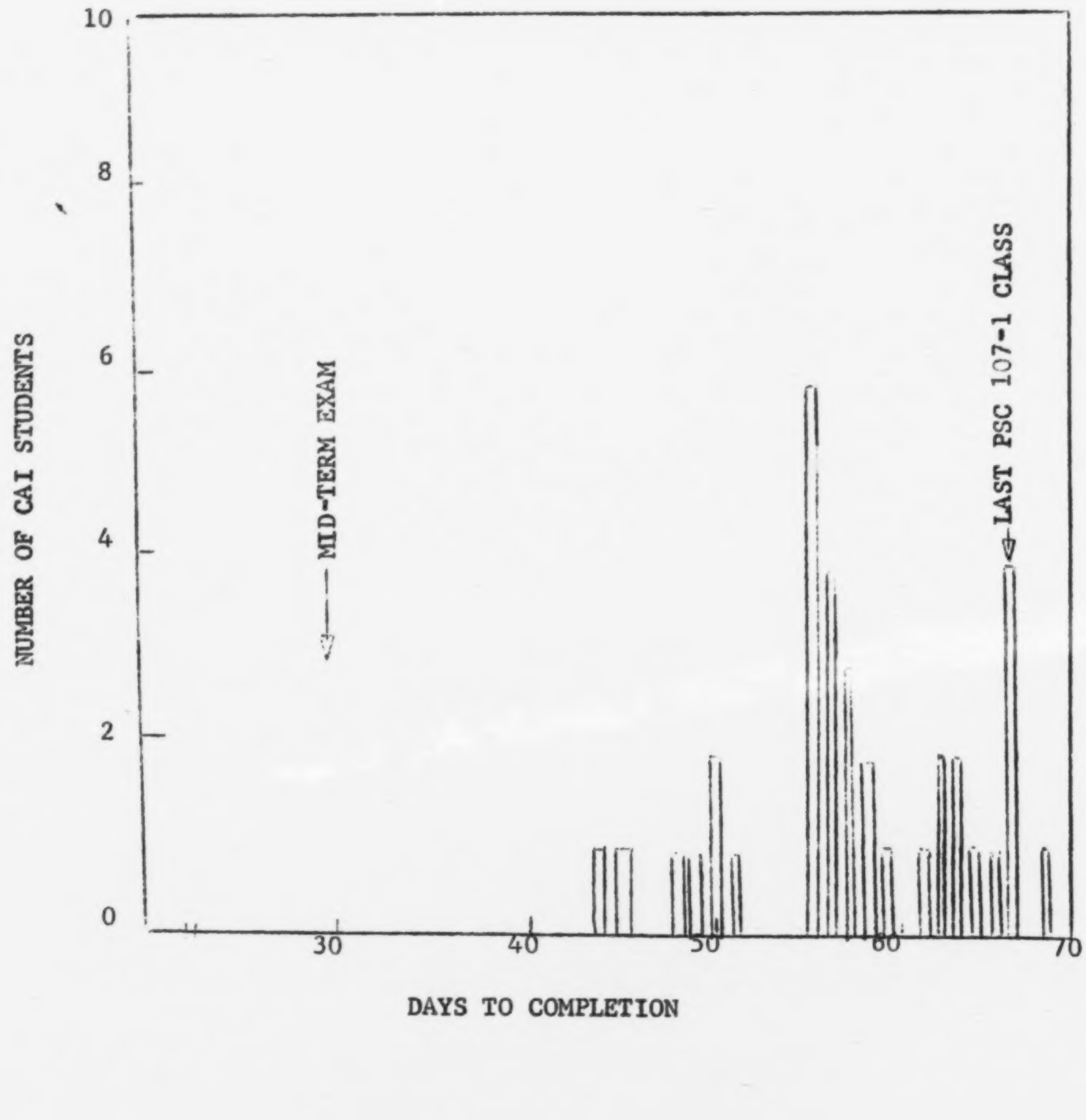


Figure 5

DAYS TO COMPLETION



The earliest exams were taken by five students on the 51st day, and all but eight students took the exam during the week preceding the 71st day.

One student went through eight lessons in one sitting, and he completed the entire course in only four visits to the CAI Center. This was possible only because he was able to skip the PSSC movies which he had already seen in high school. It is clear from Table 19 that many students found it convenient to do two or more lessons in one visit to the CAI Center.

Given the large number of multiple instructional sessions, the question of massed vs. distributed instructional procedures is immediately suggested. The massing of instructional sessions failed to inhibit the learning of the students as indicated by the lack of significant correlations between number of lessons completed per instructional session and the final grade (r = .03)

C. Comparison of Performance of the Three Treatment Groups, and Performance on the Within-Course Measures.

In order to determine whether the presentation of Physics via CAI was an effective learning situation, the performance of the CAI autonomous group was compared to the performance of two groups of subjects who had not received this treatment. These other treatment groups consisted of 1) those students attending only the conventional lectures, and 2) those students attending the conventional lectures plus receiving a four-hour examination review on the 1440 system. The mean scores for each of the three groups for the midterm examination, final examination and final grade are presented in Table 20. It may be noted that the CAI autonomous group performed slightly better than the other two treatment groups on the final examination. The one-way analyses of variance for these data indicated, however, that there was no significant difference on midterm, final or final grade between the three treatment groups.

Table 20

Mean Scores of the Three Treatment Groups on the Midterm Examination, Final Examination, and Final Grade Distribution

	Midterm	Final	Final Grade[1]
Autonomous CAI	13.32	23.65	60.62
1440 Review	13.51	22.53	58.57
Conventional	13.53	21.87	57.27

[1] Final grade is a composite score of twice the final exam score plus the midterm.

The final exam scores for the three treatment groups are plotted in Figure 6 in order that the reader may note the underlying distribution of scores. The effect of CAI (group C) appears to be one of truncating the lower grades and slightly enhancing the attainment of higher grades. To determine if these distributions of scores were significantly different, the Kormorgorov-Smirnov Test was utilized. This nonparametric statistical test focuses on the cumulative frequency distributions of two samples and determines if the sample distributions are from the same population distribution. For this test, the two samples which were utilized were 1) CAI autonomous group, and 2) conventional lecture group plus the 1440 CAI group. The results of the K-S Test indicated that the two distributions were significantly different ($\underline{D} = 8.48$; p .05). The CAI autonomous group had fewer low grades than the other group.

D. Within-Course Variables.

Performance measures were obtained on the following CAI Physics within-course variables: reading quizzes, film quizzes, lecture quizzes and A-State Anxiety Scales. The aptitude and prior knowledge variables, which were discussed in the introduction to this section, constituted the extra-course variables.

The mean proportion of "first pass" (first attempt) correct answers for the 29 lessons in the course were blocked into the five major content areas of physics. These five content areas consist of 1) introduction, 2) light, 3) mechanics, 4) electricity and magnetism, and 5) modern physics. The mean proportion first pass correct response per lesson per content area for the reading quizzes, film quizzes and lecture quizzes are present in Table 21 along with the state anxiety scales mean scores.

Table 21

Mean Proportion First Pass Correct Response for the Reading Quizzes, Film Quizzes and Lecture Quizzes, and State Anxiety Mean Scores for the Five Content Areas of Physics

	Introduction	Light	Mechanics	Electricity & Magnetism	Modern Physics
Reading Quizzes	.77	.68	.73	.63	.70
Film Quizzes	.60	.69	.74	.47	.44
Lecture Quizzes	.59	.55	.57	.48	.53
State Anxiety Scales	9.27	7.69	6.80	7.83	7.30

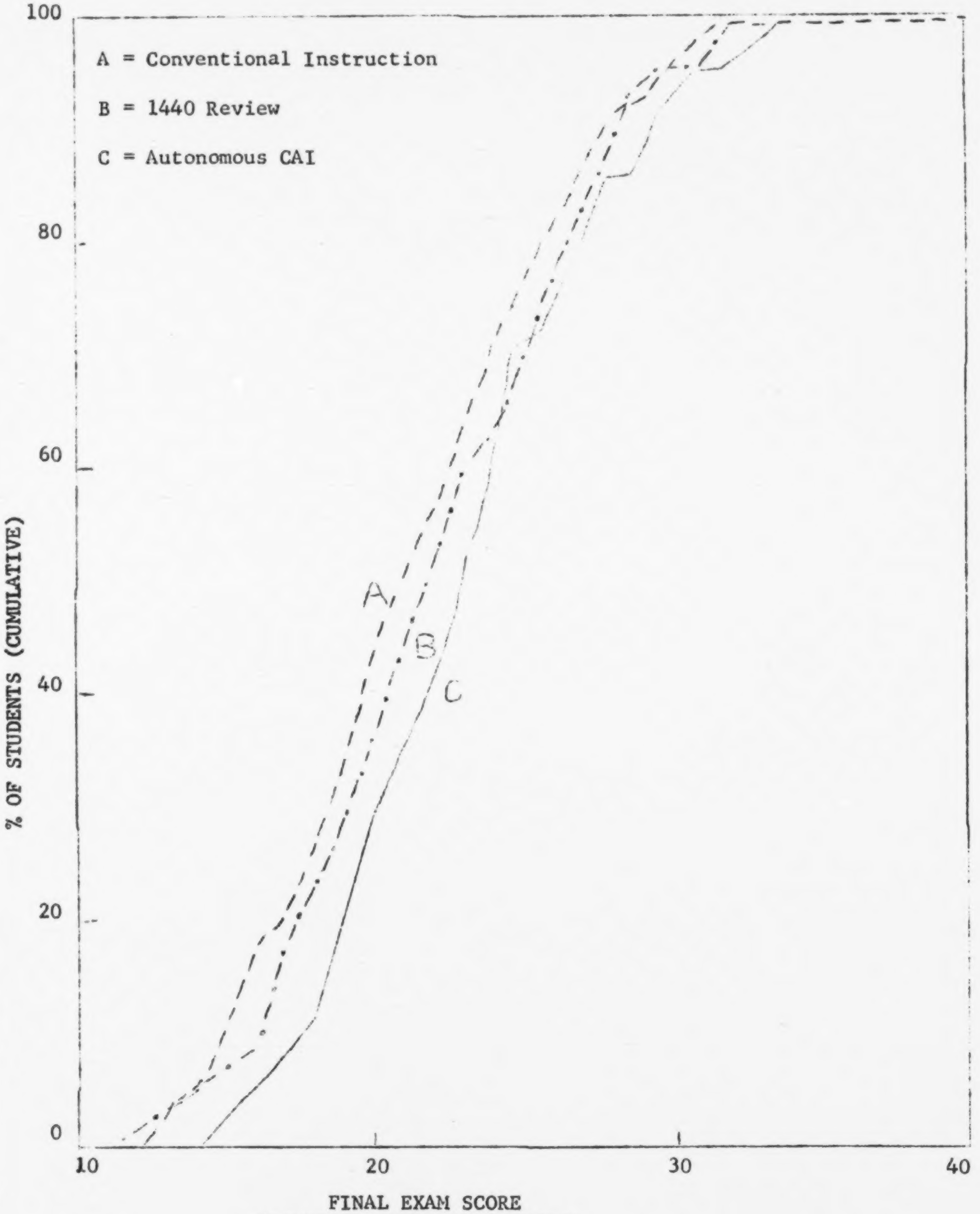

100
80
60
40
20
0
% OF STUDENTS (CUMULATIVE)
10
20
30
40
FINAL EXAM SCORE
(NUMBER OF CORRECT ANSWERS)
A = Conventional Instruction
B = 1440 Review
C = Autonomous CAI
A
B
C

Figure 6

In order to determine whether the content areas varied in difficulty, the data for each of the three types of quizzes were evaluated in a repeated measures analysis of variance design. A significant difference in the degree of difficulty was found for the reading quizzes ($F = 4.7$, $df = 4, 180$, $p < .01$); film quizzes ($F = 21.9$, $df = 4,180$, $p < .01$), and also lecture quizzes ($F = 2.9$, $df = 4,180$, $p < .05$). Since the content areas varied in difficulty, it was expected that the state anxiety scales scores would also vary systematically over time according to the difficulty of the content areas. Analysis of variance indicated that the state anxiety scales systematically varied over time ($F = 4.2$, $df = 4,180$, $p < .01$).

The means as shown in Table 21 for the reading quizzes, film quizzes, lecture quizzes and state anxiety scales were then subjected to a Duncan's Multiple Range Test to determine which of the means for each analysis was contributing to the significance of the overall F. Results of the Duncan's Multiple Range Test are presented in Table 22. It may be noted from Table 22 that only three reading quiz topics and two lecture quiz topics were significantly different. Therefore, although the overall F's were significant, the majority of these quizzes did not vary in difficulty. There was a great deal more variability in the difficulty of the film quizzes; nearly every set was significantly different from every other set. Finally, only the introductory anxiety scale scores differed from the scores on all the other topics. This implies that the anxiety ratings became stable after the first few sessions.

In general, the results of the analysis of variance and Duncan's Multiple Range Tests indicate that the content areas of CAI physics differ from each other when the mean proportion of the correct response per lesson per content area is used as a dependent variable. Anxiety, moreover, was dependent with difficulty in primarily the early lessons.

E. Relationship Among Reading Quizzes, Film Quizzes, Lecture Quizzes, and State Anxiety Scales.

In order to determine the relationships among the various within-course variables, the scores for each student on each variable, as well as his Trait Anxiety Score, were entered into a 21 x 21 correlational matrix. The significant results of this correlational procedure are presented in Tables 23a and 23b. Trait Anxiety (the 21st variable) showed no significant correlations with any of the remaining variables and, therefore, was not included in Tables 23a and 23b.[1]

In order to determine whether performance on the reading, film and lecture quizzes was consistent within each content area, the appropriate correlations were abstracted from Table 23a and 23b and presented in Table 24. It may be noted that with but three exceptions, performance among the three types of quizzes is consistent within each content area.

---

[1] This convention of not including a non-significant variable in a Table will be followed for the remainder of the Results section.

Table 22

Result of Duncan Multiple Range Test for Significant Differences Between Means of the Reading Quizzes, Film Quizzes, and A-State Anxiety Scales

Reading Quizzes

		1	2	3	4	5
Introduction	1					
Light	2	X				
Mechanics	3					
Elec. & Magn.	4	X		X		
Modern Physics	5					

Film Quizzes

		1	2	3	4	5
Introduction	1					
Light	2	X				
Mechanics	3	X				
Elec. & Magn.	4	X	X	X		
Modern Physics	5	X	X	X		

Lecture Quizzes

		1	2	3	4	5
Introduction	1					
Light	2					
Mechanics	3					
Elec. & Magn.	4	X		X		
Modern Physics	5					

A-State Anxiety Scales

		1	2	3	4	5
Introduction	1					
Light	2	X				
Mechanics	3	X				
Elec. & Magn.	4	X				
Modern Physics	5	X				

X's between means indicate a significant difference at the .05 level.

Table 23a

Significant Intercorrelations among Reading Quizzes, Film Quizzes, Lecture Quizzes, Anxiety Scales

	1	2	3	4	5	6	7	8	9	10
1. Introduction (A)	1.00		.36	.34						
2. Light (A)		1.00	.56	.53	.38	.39	.45			
3. Mechanics (A)			1.00	.64	.50	.60	.39	.34	.50	
4. Modern Physics (A)				1.00	.74	.40	.52		.44	
5. Modern Physics (A)					1.00	.43	.48		.36	
6. Introduction (B)						1.00	.59		.36	
7. Light (B)							1.00		.37	
8. Mechanics (B)								1.00		.34
9. Elec. & Magn. (B)									1.00	
10. Modern Physics (B)										1.00

Note: Correlations above .43 ($p < .01$); all other correlations ($p < .05$)

A = reading quiz
B = film quiz
C = lecture quiz
D = State Anxiety Scale

Table 23b-continued
Significant Intercorrelations among Reading Quizzes, Film Quizzes, Lecture Quizzes and Anxiety Scales

	11	12	13	14	15	16	17	18	19	20
Introduction (A)	.34	.41	.42							
Light (A)	.39	.35	.50		.48					-.42
Mechanics (A)	.46	.34	.59	.47	.45	-.48	-.39	-.42	-.47	-.44
Elec. & Magn. (A)			.53	.53	.46					
Modern Physics (A)				.41	.45	.55				
Introduction (B)	.34	.54	.60	.38	.37					
Light (B)		.57	.45	.46	.33					
Mechanics (B)	.34	.38				-.37	-.38	-.37		
Elec. & Magn. (B)			.50	.60	.41	-.39				
Modern Physics (B)				.38	.38					
Introduction (C)	1.00		.56			-.38	-.49		-.41	
Light (C)		1.00	.52	.33	.45					
Mechanics (C)			1.00	.66	.62	-.34				
Elec. & Magn. (C)				1.00	.58					
Modern Physics (C)					1.00					
Introduction (D)						1.00	.63	.57	.66	.56
Light (D)							1.00	.76	.67	.53
Mechanics (D)								1.00	.71	.56
Elec. & Magn. (D)									1.00	.83
Modern Physics (D)										1.00

Table 24

Significant Intercorrelations of Reading Quizzes, Film Quizzes, and Lecture Quizzes Within Each Content Area

Content Area	r_{AB}	r_{AC}	r_{BC}
Introduction		.34	.34
Light	.45	.35	.57
Mechanics	.34	.59	
Electricity and Magnetism	.44	.53	.60
Modern Physics		.55	.38

A = Reading Quiz
B = Film Quiz
C = Lecture Quiz

Correlations above .43 ($p < .01$); all others significant ($p < .05$)

From the preceding analysis it is clear that there was a significant relationship among the students' responses within the various content areas. In order to determine whether performance in one content area was related to performance on a subsequent content area, the correlation of each reading, film, and lecture quiz with the reading, film, and lecture quiz in the following content area was abstracted from Tables 23a and 23b. These significant correlations are presented in Table 25. Reading quizzes were consistent across time as were the lecture quizzes as shown by their significant correlations with subsequent reading and lecture quizzes. However,

Table 25

Correlation of Performance on Reading Quizzes, Film Quizzes, and Lecture Quizzes with Subsequent Performance

Quizzes	r_{AB}	r_{BC}	r_{CD}	r_{DE}
Reading Quizzes		.56	.64	.74
Film Quizzes	.59			
Lecture Quizzes		.52	.33	.62

A = Introduction B = Light C = Mechanics D = Electricity & Magnetism E = Modern Physics

Correlations above .43 ($p < .01$); all other significant ($p < .05$)

there was only one significant correlation between performance on one content area of film quizzes compared to the following content area of film quizzes. This lack of correlation reflects the erratic performance of the students on the film quizzes.

Since there were significant relationships among reading, film, and lecture quizzes within content areas (Table 24), it was expected that anxiety and quiz performance would correlate within a content area. The significant correlations are presented in Table 26. There were, in fact, relatively few significant correlations between anxiety and quiz performance.

Table 26

Significant Correlations of State Anxiety Scales Within Reading Film, and Lecture Quizzes within the Content Areas of CAI Physics

STATE ANXIETY	READING QUIZZES	FILM QUIZZES	LECTURE QUIZZES
Introduction			-.38
Light			
Mechanics	-.42	-.37	
Electricity & Magnetism			
Modern Physics			

Correlations reported are significant ($p < .05$)

In order to determine whether the State-Anxiety scales were consistent across content areas, the scores on the A-State anxiety scales for the five content areas were correlated. These correlations are presented in Table 27. It may be noted that A-State scales are highly related throughout the course; students reported their anxiety level in a very consistent manner. Thus the individual difference variable of anxiety was a consistent index throughout the instructional sequence.

Table 27

Intercorrelations of A-State Scales in the Five Content Areas of CAI Physics

Anxiety	1	2	3	4	5
Introduction (1)	1.00				
Light (2)	.63	1.00			
Mechanics (3)	.57	.76	1.00		
Elec. & Magn. (4)	.66	.67	.71	1.00	
Modern Physics (5)	.56	.53	.56	.85	1.00

F. Extra-Course Variables

Relationships among aptitude and prior knowledge variables. In order to ascertain the relationship among these entering behavioral variables, a 10 x 10 correlational matrix was constructed. Significant results of this correlational procedure are presented in Table 28. It may be noted that the type of high school physics was correlated with critical thinking, logical reasoning, and the Mathematics total score. The significant positive correlations indicate that students with PSSC physics in high school scored higher on the critical thinking, logical reasoning, and mathematics tests. In addition, tests which measured mathematical ability correlated significantly with tests that measured critical thinking.

G. Relationships between aptitude and prior knowledge variable with course performance.

Reading quizzes, film quizzes, lecture quizzes and anxiety scales for the five content areas were correlated with the prior knowledge and aptitude variables. There were no significant correlations between aptitude and prior knowledge variables with reading quizzes or film quizzes. There were scattered significant correlations with the lecture quizzes; these results are presented in Table 29. There was only one significant correlation between aptitude or prior knowledge variables and anxiety scores. Math aptitude significantly correlated with the anxiety scale ($r = -.36$) in the electricity and magnetism content areas.

Table 28

Intercorrelations among Aptitude and Prior Knowledge Variables

	1	2	3	4	5	6	7	8	9	10
1. Type H. S. Physics										
2. College Math. Level										
3. Critical Thinking		.33								
4. Critical Thinking	.39		.31							
5. Critical Thinking Total		.33	.77	.33						
6. Listening (immediate recall)										
7. Math. Apt.			.42	.31	.45	.34				
8. Logical Reason.	.42									
9. Math. Total	.32					.31	.57	.72		
10. Ships Destin.						.52	.55	.27	.55	

Note: Correlations above .43 ($p < .01$); all others significant (p .05)

Table 29

Significant Correlations of Aptitude and Prior Knowledge with Lecture Quizzes

	LECTURE QUIZES				
	(1) Intro-duction	(2) Light	(3) Mech.	(4) Elec.Magn.	(5) Modern Physics
College Math Level	.37				
Listening (immediate Recall)			.34		.37
Math Aptitude			.36		
Logical Reasoning					.33
Math Total			.34		.34

Note: Correlations reported significant ($p < .05$).

H. Relationship between reading quizzes, film quizzes, lecture quizzes, anxiety scales, and final grade.

The significant correlations of the reading quizzes, film quizzes, lecture quizzes, and A-State anxiety scales for each content area with the final grade are shown in Table 30. The final grade (FGRD) is a composite score of twice the score on the final exams plus the score on the midterm exam. This composite score was utilized by the

Table 30

Significant Correlations of Film and Lecture Quizzes with Final Grade

	FGRD
Film Quizzes	
Introduction	.38
Lecture Quizzes	
Introduction	.35
Light	.47
Mechanics	.59
Elect. & Mag.	.38
Modern Physics	.33

Note: Correlations above .43 ($p < .01$); all other correlation ($p < .05$).

instructor in the conventional course to determine the final grade in the course. Note that none of the reading quizzes or A-State scales, and only one of the film quizzes correlated with the final grade. However, all of the lecture quizzes correlated with the final grade.

I. Relationship between aptitude and prior knowledge variables with final grade.

The significant correlations of the aptitude and prior knowledge measures with the final grade are presented in Table 31. Three major classes of variables significantly correlated with the final grade: 1) type and grade in high school physics, 2) critical thinking and mathematical ability, 3) and listening (immediate recall).

Table 31

Significant Correlations of Aptitude and Prior Knowledge Variables with the Final Grade

Variable	Correlation
1. Type H.S. Physics	.44
2. H.S. Physics Grade[1]	.45
3. College Math. Level	.48
4. Critical Thinking Test 3	.33
5. Critical Thinking Test 5	.39
6. Listening (immediate recall)[2]	.40
7. Math. Aptitude	.36
8. Logical Reasoning	.32
9. Math. Total	.43

Note: Correlation above .43 ($p < .01$) other correlations ($p < .05$).

[1] $n = 21$; p .05

[2] $n = 36$; p .05

Results of the regression analysis of prior knowledge and aptitude variables on the final grade are presented in Table 32. The significant multiple R for the five steps in the regression equation was .70 (32 df $p < .01$. Prior knowledge (high school physics and college math level) and aptitude variables (critical thinking, logical reasoning, and immediate recall) did predict the final exam score. The first five variables entered into the stepwise regression accounted for 48 per cent of the variance of the final grade when only prior knowledge and apptitude variables are considered.

Table 32

Results of Stepwise Regression of Aptitude and Prior Knowledge Variables on the Final Grade

Variable	r(FGRD)	R	R^2
1. Type of H. S. Physics	.44	.44	.20
2. Critical Thinking Total	.31	.59	.35
3. Listening (immediate recall)	.40	.64	.41
4. Math Level	.48	.67	.45
5. Logical Reasoning	.32	.70	.48

J. Relationship of reading quizzes, film quizzes, lecture quizzes, anxiety scales, aptitude and prior knowledge variables with final grades.

The inclusive regression analysis is presented in Table 33. The multiple R for the 10 steps of the regression analysis is .86 (27 df, $p < .01$) which is significant. The CAI lecture quiz on mechanics contributed the most to the explanation of the variance of the final grade. The low or negative relationship of reading quiz scores (variables 2, 7 and 8), make it appear that these scores are acting as suppressor variables and can be interpreted as reflecting the orientation of the students to this component of the curriculum. (The total of all reading quiz performances contributed marginally, R = .320; see Table 24.) The Critical Thinking aptitude variable and High School physics prior knowledge variable are contributing, probably, because of their high relationship to problem solving ability.

Listening ability and trait anxiety reflect the potential for individual difference by CAI treatment effects. It may be noted that, in general, films contributed very little to the prediction of final criterion performance.

Table 33

Multiple Regression Analysis of Aptitude, Prior Knowledge, and Within-Course Performance on Final Grade

	Variables	r(FGRD)	R	R^2
1.	Classical Mechanics Lecture Quiz	.59	.59	.35
2.	Reading Quiz on Modern Physics	-.08	.69	.48
3.	Critical Thinking Test	.36	.74	.55
4.	H. S. Physics	.38	.78	.61
5.	Light Theory Lecture Quiz	.47	.81	.66
6.	Listening Test	.38	.82	.68
7.	Reading Quiz on Measurement	.17	.83	.69
8.	Reading Quiz on Light	.11	.84	.71
9.	Trait Anxiety	.01	.85	.72
10.	Film Quiz on Light Theory	.14	.86	.73

It may be noted that type of physics background, i.e., none, traditional, or PSSC predicted a substantial portion of the variance on the final grade. The mean final grades for the students with the three types of high school physics background were, 56.5 (SD = 9.4), 58.6 (SD = 9.3), and 66.5 (SD = 9.2) respectively. To further investigate which type of physics background contributed to success on the final grade, a one-way analysis of variance for these data was computed in which the main effect of treatment was significant (F = 3.1, df = 2,34, P .05). Thus significant main effect indicated that students with PSSC background in high school received higher final grades than the students who had traditional physics instruction, or none at all.

K. Pre Course Interview Data

Student attitudes for the CAI autonomous group were sampled during interviews conducted at the beginning of the course. These results are presented in Table 34. Most of the students (58%) described their attitude towards physics as "moderately interested," on a scale ranging from strong interest to strong dislike. From a suggested list of

Table 34

Pre-Course Interview Data[1]

1. What is your interest towards math, physics and chemistry?

	Math	Physics	Chemistry
Strong Interest	33	13	10
Moderate Interest	25	58	33
Indifferent	25	15	25
Moderate Dislike	5	3	18
Strong Dislike	8		
No Exposure		10	8

2. What were your reasons for taking P107?

	1st choice	2d choice	3rd choice	4th choice
Required	30	8	5	3
Best choice among science electives	40	10		3
To learn about physics	18	13	8	
Easy course	3	5	3	5
Other	3		3	

3. What were your reasons for taking CAI P107?

	Choice							
	1st	2nd	3rd	4th	5th	6th	7th	8th
Progressing at own speed	23	18	10		3	3		
Chose own class times	13	15	13	3	8			
Curiosity about CAI	40	8	8	8	8		3	
CAI more personalized	10	3	3	3	3	5		
Less time-consuming	5	5	3			3		3
Opportunity to learn more than in class	10	10	5	5				3
Dislike for large classroom	5	13	3	3		5		
Recommended	3	3	3	3		3		

4. Do you plan to use lab in P107?

Yes	No	No reply
5	90	5

Note: Numbers = % of students responding

[1] N = 39; two students later dropped course

reasons for taking any physics course, many students (40%) said it was the best choice of science electives, some (30%) took it because it was required and a few (18%) admitted to taking it to learn more about physics. Curiosity about CAI (40%) was chosen as the reason for taking the CAI course, while 36% of the students chose CAI Physics so that they could progress at their own rate. Most students (90%) did not plan to take a physics lab in conjunction with the course.

L. Interview Data Gathered after Course Completion

The CAI Physics students were also interviewed individually one to three weeks after the final exam. The student responses (N=37) were tape-recorded and then coded. The students' responses to this relatively structured interview have been grouped into six categories. These six categories are: 1) attitudes toward CAI; 2) attitudes toward anxiety measurement; 3) comments on the course organization; 4) assessment of difficult areas in P107; 5) use of various media; and 6) biographical data. The detailed response analysis forms and tabulated results may be found in Appendix J.

M. Attitudes Toward Using CAI

Most students responded that they like CAI (79%); that they would take another course on CAI (73%); and that they would recommend CAI Physics to another student (79%). Ninety-five per cent of the students liked the self-pacing aspect of the CAI course, and only twenty-seven per cent felt that there was less personal contact with CAI. Most students (90%) felt that knowledge was gained using CAI.

About half the students preferred the 1500 system to the 1440 system with 23% stating "no preference." When students were asked their response preference on the 1500 system, i.e., whether to use a light pen or a keyboard, 78% of the students preferred using the light pen (i.e., multiple choice) while 68% preferred multiple choice format rather than constructed response format on the 1440 system.

In general, the attitudes toward the CAI course were slightly more positive before the student started the course as compared to afterwards. Seventy-three per cent responded that they had positive attitudes toward CAI before the course, while after the course only 56% of the students responded with a positive attitude. The difference is seen in the change of 5% neutral before the course to 25% neutral after the course.

N. Assessment of Anxiety Scales

When asked what they felt was the purpose of the anxiety questions, the largest percentage of students indicated that they were to measure their reaction to the computer (27%) while 17% could state no opinion. Most students said that they responded sincerely (73%) and yet, they did not spend a large amount of time answering (62%). Indication is given that the students were not bothered by the questions in that 81% felt that they were appropriately placed in the sessions and that the number and length of the questions were not excessive (70% and 89%, respectively).

In assessing when their anxiety was highest, 15% indicated that it was at the beginning of the course, 16% said it was after poor performance on the lessons, and 10% noted it when the material was difficult. Small percentages indicated other times, while 11% said they experienced no anxiety.

O. Course organization

Most students felt that the overall organization of the course was good or satisfactory (87%). Only 27% felt that the test questions were of poor quality, while 63% felt that there should have been more questions; forty-six per cent felt that the lessons were too long. In general, the students indicated that the reading quizzes were of sufficient quality (70%), and that the film quizzes were helpful (60%). Although only 52% indicated that the lecture quizzes were thorough or satisfactory, the majority of the students felt that the lectures and the supplemental lecture notes were easy to understand (67% and 90% respectively) and that the lectures were the correct length (70%). However, 80% indicated that the use of a variety of voices would have enhanced the lectures. The short films and film notes were given tacit approval in that 70% said that the short films were helpful at least sometimes, that they were easy to understand (71%) and that the film notes contained sufficient information (68%).

P. Difficulty with Physics Concepts or Memory Difficulties

Concerning the question of difficult concepts in CAI Physics, most students replied that they either felt there were no difficult concepts (40%) or that electricity (19%) and magnetic fields (19%) were the most difficult. In addition, most students (65%) responded that the mathematics in the CAI physics course was easy. With regard to memory difficulty, most students (43%) responded that there were no specific retention problems. The topics that were mentioned as memory problems were, in the main, those also mentioned as difficult concepts. Fourteen per cent reported trouble remembering topics on electricity, 10% had memory problems with magnetic fields, and 10% reported problems remembering various formulas.

Q. Use of Various Media

Most students (73%) in the CAI autonomous group spent 1/2 hour to 1 hour preparing for a lesson. In preparation for an exam, moreover, students used a combination of computer review (62%), notes (46%), and the textbook (54%). It may be noted that these figures add up to more than 100% as students used multiple sources when preparing for an exam. Only 67% of the students saw 75% or more of the films;

however, 30% of the students indicated that they had seen some of the films before. Sixty-seven per cent of the students did take notes on the long films, and many students (73%) would use film notes if they were furnished.

With regard to the 8mm film notes, 45% used them most or all of the time and they used the notes about equally before (49%), during (35%) and after the film (54%). It may also be noted that these percentages are greater than one as students made multiple uses of the film notes. Eighty-six percent of the students indicated that they took their own notes on the lectures. In addition, 68% of the students used all or most of the supplementary lecture notes. These supplementary notes were used mainly during the lecture (93%) and after the lecture (54%). It may be noted that these numbers are also greater than 100% as multiple uses were made of lecture notes.

R. Biographical Data

Of the 37 students in CAI autonomous group, 33% had PSSC Physics in high school, 30% of the students had taken a regular physics course, and 32% of the students had no physics at all. There were 20 females and 17 males. Mainly freshmen (62%) participated in the experiment. The math level for the majority of the students was basic college math (57%).

S. Summary of Spring, 1968 Field Study

Following the revision of the CAI Physics course during the Winter quarter, a second field study was conducted in the Spring with 37 students.

The results indicate that although there was no significant difference in the test performance of the CAI group in comparison to either a conventional lecture group or a group which also reviewed on the 1440, there was a learning time savings of approximately 12 per cent.

Analysis of student performance on within-course measures indicated stability across and within lessons with the exception of the film quizzes. The anxiety measure was not generally correlated with within-course performance. The multiple R for predicting final grade in course, using the 10 best background and within-course measures was .86.

The post-course interview data reflected a generally positive attitude on the part of the students. The course organization was highly satisfactory and none of the course concepts were judged to be unduely difficult. About half the students preferred the 1500 CRT system, 27 per cent preferred the 1440 typewriter system, and 23 per cent had no preference.

VIII

Field Study: Fall, 1968

A. Introduction

The overall success of the CAI physics course as evidenced by the Fall 1967 and Spring 1968 sections of this report provided the opportunity to investigate further into the nature of individualized media instruction. Hopefully the answers to new questions which have arisen will in the future provide guidelines to more efficient uses of technology in instruction.

One of these areas of interest is individualization in the context of person by media interaction. In the instructional framework, the question becomes: Are particular individuals better suited to a specific media due to their peculiar interest or personality characteristics?

A second question vis-a-vis the improvement of the use of instructional technology is concerned with the best expenditure of student time beyond that of exposure to media. Since it has been shown that basic physics knowledge is being acquired through CAI and instructional media, what is the effect of augmenting a computer-based media presentation with student enriched discussion?

B. FLEX Physics 107

To answer these questions, 22 student volunteers who participated in a year-long Freshman Learning Experience (FLEX) were used in the Fall, 1968 field study. The FLEX program replaced standard class structure and meetings with less formal and more flexible arrangements for student-instructor interaction. Twenty-two student volunteers were selected from the population of incoming FSU freshmen representing the modal students, i.e., participants in FLEX do not represent the unusually well-prepared (or intellectually well-endowed) freshmen, nor do they represent the students who are marginally prepared for college work. Freshman students who fit into the modal category were informed of the FLEX program and applications for participation were invited.

The FLEX curriculum requires a natural science course for non-science majors. Since FLEX students have all shown a preliminary interest in majoring in the humanities, they could fulfill this requirement by completing the CAI physics course. However, the CAI/Media physics course used in this study was not the complete autonomous course heretofore described. This field study utilized a modified version of the CAI course from which all reading assignments and some PSSC films plus associated CAI materials were deleted in order to provide about two-thirds of the normal course load. In this context, the instructional aim of the CAI/Media program was to enable these students to acquire the basic physics knowledge in no more than two-thirds of the time that they had available for physics, i.e., no more than two out of the three contact hours which are available per week. The remaining hour per week was used for classroom discussion and presentation of enrichment concepts of potential value to these non-science majors. The physics instruction which the FLEX students received, therefore, consisted of two major parts:

(1) Students received the 29 lessons available on the 1500 CAI/Media system. This constituted the "basic objectives" of the physics course.

(2) In addition, students received instruction for one hour per week with a physics professor in a recitation session.

Thus, the project provided a means of investigating both student by instructional treatment interaction, and CAI/Media augmented by recitation sessions.

Design

The 29 lessons comprising the CAI/Media physics course were made available on the IBM 1500 Instructional System to the FLEX students. A comparative control group of 22 student volunteers from a large lecture section of a parallel classroom/lecture course was obtained. The following battery of pre-treatment instruments was administered to each student: 1) The Florida Twelfth Grade Achievement Test; 2) a physics pretest; 3) a background questionnaire to obtain the number of high school mathematics and science courses each student had taken; 4) the FACT questionnaire, developed by the Division of Instructional Research and Service at FSU, a psychological testing instrument which views the style of academic inquiry as a correlate of academic success; 5) the College Student Questionnaire (CSQ) developed by Educational Testing Service; and 6) the Omnibus Personality Inventory (OPI) developed by the Center for the Study of Higher Education, University of California, Berkeley.

During the treatment period of one academic quarter of instruction, data were gathered on the following variables: 1) mid-term examination; 2) attitude toward instructional mode; 3) test anxiety during the mid-term examination[2]; and 4) test anxiety during the final examination. Finally, post-treatment or retention data were gathered on two separate final examinations and on final course grade.

In summary, this study proposed to investigate the following: 1) How do the experimental and control groups comparatively perform? 2) Who are the greatest beneficiaries of the CAI/Media with recitation course, the bright or not-so-bright students? and 3) Do various personality variables interact with modes of instruction?

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[2] Anxiety scores were gathered with the short form of the Spielberger State Anxiety Scale developed by O'Neil, et al. (1968).

D. Analysis: Comparative evaluation of end-of-term performance

The results of four analyses of covariance to assess the comparative performance of the FLEX and control groups appear in Tables 35 and 36.

Table 35

Analysis of Covariance: FLEX vs. Control on Conventional Final Examination (Final I)

Source	df	MS	F
Presentation Method			
Error (within)	40	21.77	
Total	41		
Difference for testing adjusted treatment means	1	188.85	8.67**
Adjusted treatment means:			
FLEX 22.07			
Control 26.52			

** P < .01

Table 36

Analysis of Covariance: FLEX vs. Control on FLEX Final Examination (Final II)

Source	df	MS	F
Presentation Method			
Error (within)	40	6.49	
Total	41		
Difference for testing adjusted treatment means	1	224.4	34.59***
Adjusted treatment means:			
FLEX .74			
Control 3.89			

*** P < .001

The covariates in each case were the pretest and the Florida Twelfth Grade Examination Scores. Table 35 shows that the control group performed significantly better than the FLEX group on the conventional final examination which was the end-of-term examination authored by the classroom/lecture professors. Conversely, the FLEX group performed significantly better on the FLEX final examination, which was prepared by their own recitation professor, (see Table 36). Table 37 indicates that significant differences were not found, however, between the groups on final grade achievement. An additional analysis indicates there was no significant difference in performance on the traditional examination (Final I) when the control group is compared only to those members of the FLEX group who had finished all 29 lessons of the revised CAI/Media course (Table 38).

Table 37

Analysis of Covariance:

Flex vs. Control on Final Grade in Course

Source	df	MS	F
Presentation Method		6.37	
Error (within)	40		
Total	41		
Difference for testing adjusted treatment means	1	.34	1
Adjusted treatment means:			
FLEX 9.25			
Control 9.06			

Table 38

Analysis of Covariance:

FLEX S's Finishing All 29 Lessons vs. Control

Source	df	MS	F
Presentation Method			
Error (within)	31	23.14	
Total	32		
Difference for testing adjusted treatment means	1	86.10	3.72*
Adjusted treatment means:			
FLEX 23.13			
Control 26.56			

* Not significant at P = .05

This last result is consistent with a within FLEX group analysis which examined the differences in performance on the conventional final examination of 15 students who completed the entire CAI/Media course as oppose to seven students who completed 24 or fewer of the 29 CAI/Media lessons. A mean difference analysis showed statistically significant superiority of the students completing all of the lessons ($\bar{X}$ completed = 22.9; $\bar{X}$ not completed = 18.8; t = 2.62, p .02)

E. Analysis of Treatment by Ability Relationships

It is of interest to determine whether one or the other instructional treatments benefited the bright students more than the not-so-bright or vice versa. To examine this question, the five students with the highest Florida Twelfth Grade scores and the five with the lowest scores from each group were identified. Mean scores were then computed for both of the subgroups on five additional variables: pretest, midterm examination, Final I, Final II, and course grade. One additional variable, number of CAI lessons completed, was analyzed for the FLEX group. The mean differences of the variables from each subgroup (bright verses not-so-bright) were examined and interpreted in light of variance ratios. Classical parametric statistical procedures were not used due to the small N's involved. These results are reported in Table 39.

Table 39

Analysis of Top Five Students and Low Five Students

rol Group riables:	12th Grade	Pretest	Midterm	Final I	Final II	Course Grade
op students' ean scores N=5)	474.4	20.8	16.8	28.6	5.4	10.6
ottom students' ean scores N=5)	395.0	16.0	13.6	25.2	3.4	8.6
otal group ean scores N=22)	435.2	16.9	15.1	26.9	3.9	9.3
otal group tandard devia-ions (N=22)	30.1	4.4	2.6	5.6	3.1	2.8
ine 1-Line2/ ine 4 $\bar{X}_t\bar{X}_b/\sigma$)	2.64	1.09	1.23	.61	.65	.71

Group riables:	12th Grade	Pre-test	Mid-term	CAI Lessons Comp.	Final I	Final II	Course Grade
op students' ean scores N=5)	475.4	14.8	15.2	25.6	22.0	8.4	9.2
ottom stu-ent's mean cores(N=5)	354.2	11.0	12.2	20.8	18.8	9.6	7.8
otal group ean scores (N=22)	421.5	13.5	13.7	24.9	21.6	8.8	9.0
otal group standard deviations (N=22)	49.7	4.7	2.8	7.3	3.9	1.7	2.3
ine 1-Line2/ ($\bar{X}_t\bar{X}_b/\sigma$)	2.44	.81	1.07	.65	.82	-.70	.61

It can be seen by comparing line five for the control group with line five from the FLEX group that there is relatively little difference between treatments. That is, the progression of larger difference ratios getting smaller from the beginning to the end of the course is similar for both groups. The one exception to this is Final II. There is a negative ratio for the FLEX group of approximately the same magnitude as the positive ratio for the control group. This negative function is a reflection of the less bright students performing with higher proficiency on Final II.

The similar patterns in the ratios on line five for the control group and line five for the FLEX group offer evidence that for both treatments the P107 course apparently has a collapsing or equalizing effect on students. The bright and not-so-bright students' terminal behaviors are generally the same regardless of their entry behavior. The interpretation for this is expanded in the discussion section.

F. The Interaction of Personality Characteristics With Modes of Instruction

Evaluation of this question was obtained by performing two separate stepwise multiple regression analyses. Both analyses regressed on the dependent variable Conventional Final I, the variables of attitude, personality, and background measures which were administered prior to the instructional treatments. For the FLEX group, the multiple R^2 (adjusted for small N), after extracting the first nine variables was .53. For the control group, the adjusted multiple R^2 after extracting nine variables was .76.

Table 40 shows the independent correlational relationships with the dependent variable as well as variance estimates (R^2) for each of the variables extracted. It should be noted that five of the nine predictor variables in each regression are unique to the group on which the regression was performed, while four of the variables are common to both groups. The variables acting as common predictors are the Omnibus Personality Inventory (OPI), Masculinity-Feminity scale, the OPI Religious Orientation scale, number of background courses in high school math and science, and Florida Twelfth Grade Achievement scores.

Further examination of Table 40 indicates that the five variables unique to the control group in terms of predicting final examination success. These were: OPI Theoretical Orientation, OPI Impulse Expression, OPI Practical Outlook, College Student Questionnaire (CSQ) Liberalism and CSQ Peer Independence. In contrast, the five variables unique to the regression equation for the FLEX group are as follows: The FACT Questionnaire, OPI Altruism, OPI Estheticism, OPI Response Bias and CSQ Social Conscience. Comparative discussion of these scales for the two groups is pursued in the following discussion.

Table 40

Stepwise Multiple Regression Variance Estimates

Control Group

Variable Extracted	Pearson r	R^2
Omnibus Personality Inventory (OPI) Masculinity- Femininity	.62	.38
Florida Twelfth Grade Score (TWTH)	.45	.54
OPI Theoretical Orientation*	.04	.60
OPI Religious Orientation	.38	.69
OPI Impulse Expression *	-.25	.77
OPI Practical Outlook*	-.34	.80
Background in Math & Physics (BKGD)	-.22	.82
College Student Questionnaire (CSQ) Liberalism*	.17	.84
CSQ Peer Independence *	.31	.85 (.76)**

* Indicates variable unique to control group regression equation

** R^2 adjusted for sample size

FLEX Group

Variable Extracted	Pearson r	R^2
OPI Masculinity-Femininity	-.44	.19
FACT *	-.11	.33
OPI Altruism	.17	.40
OPI Religious Orientation	.10	.48
OPI Estheticism*	-.30	.53
OPI Response Bias*	.01	.58
BKGD	-.10	.61
CSQ Social Conscience*	.07	.65
TWTH	.22	.71 (.53)**

* Indicates variable unique to FLEX group regression equation

** R^2 adjusted for sample size

G. Discussion

The analyses which revealed that each group performed better on the exams developed by the professor with whom they had their instructional contact is not surprising. This finding is consistent with the problem that curriculum developers have when trying to compare results of new programs which have dissimilar criterion objectives. The additional implication is that students generally tend to place the credibility of their information source in the instructor to whom they are exposed. However, the results of the analysis of covariance between the students in the FLEX group who finished the CAI/Media lessons and those students in the entire control group suggest that the students who finish even the less inclusive, modified version of the CAI/Media course perform as well as the students instructed by lecture when the dependent measure is the traditional lecture-based final examination.

Results of the small sample description evaluation of the high aptitude-low aptitude students led to the following interpretation:

Examination of the mean differences to total group variability (standard deviation) ratios shows ratios of 2.64 and 2.44 for the control and FLEX groups, respectively, on Florida Twelfth Grade scores (Table 39). This is the variable upon which the groups were subdivided and the ratios indeed show that the top students of each group were substantially more academically qualified at the beginning of the program than the bottom students.

Examining only the control group subjects, it can be seen that this group also had a large difference ratio for pretest scores (1.09), reflecting a substantial difference between the means of the high and low groups (4.8 points). This difference for the midterm of the control group is increased to 1.23 which suggests that by the time of the first exam these students were out-performing the low students by a significant margin (3.2 points). However, a noticeable decrease in the size of the difference ratios was found for Final I, Final II and course grade. The decrease in ratio size here can be interpreted as indicating that by final exam time, the students who were potentially more qualified at the beginning of the course were not out-performing the slower students by as great a margin as would be expected from their entry skills.

One hypothesis to account for this change is that the impact of the course somehow led to the restricting of the range of student performance. That is, the brighter students were performing more like the not-so-bright students at the end of the course than they were in the beginning. The corollary, obviously, presents just as tenable a hypothesis; the not-so-bright students were performing more like the bright students due to the course content and impact. The first hypothesis could be supported by reasoning that the brighter students interpreted the course content and their better performance on the midterm as a sign that P107 was relatively easy. Perhaps these students slacked off in their study effort and, therefore, failed to distinguish themselves in the final examination. It is equally fair to assume that the less bright students simply worked harder after the midterm exam, which showed them they had not grasped as much of the materials as the brighter students. Upon recognition of this deficiency, they may have increased their performance simply through increased effort.

Whatever the effects which led to the terminal performance of the two groups becoming similar, whether it was the content of the course or the individual working patterns of the students, the influence of the instructor should not be overlooked. A possible interactive effect may have been caused by the professor of the lecture class alienating the brighter students with his approach and perhaps encouraging the less bright students by his presentation. While these interpretations are speculative, the important point is that the terminal behaviours of the bright and not-so-bright students in the control group did approach a similarity which was not anticipated from examination of their entry skills.

The analysis of bright and not-so-bright students in the FLEX group showed an almost identical pattern of mean difference to variance ratios as the control group. This pattern suggests the same restricting effect on performance at the end of the course as found for the control group. Close inspection of Table 39 shows only subtle differences in the trend or pattern of ratios for the FLEX students, with the exception of the ratio under Final II, the exam based on the recitation sessions. The negative ratio for Final II is a reflection of the fact that less bright students performed at a higher level of proficiency than the brighter students. Several explanations for this result present themselves. First, the less bright students could very well have considered their recitation professor the most relevant source of basic physics information. Since it is already known from their Florida Twelfth Grade Examination scores that these students were not strong academically, it is reasonable to assume that their textbook study habits were not as good as the brighter students; so these students may have attended more closely during recitation and placed more emphasis on studying notes taken from those meetings. And, since Final II was heavily weighted toward the materials introduced during the recitations and not found in the CAI course, it would follow that this group of students would perform better on that examination.

Second, the brighter students may have felt that much of the discussion during recitation was redundant with the CAI/Media information. Therefore, these students placed their study emphasis on the CAI/Media materials. Their superior average performance on Final I (3.2 points) in comparison with the not-so-bright students is concurrent with this hypothesis. Further, the fact that the variance ratio of the FLEX group under Final I is not quite as small as it is for the control group (.82 vs. .61) suggests that there is a slightly greater terminal performance discrepancy for the FLEX group. This may be due to the bright students having studied the CAI/Media materials (upon which Final I is based) more carefully while the less bright relied on the information obtained during the recitation sessions. Additional support for this hypothesis is found in Table 39 under the column headed "Number of CAI Lessons Completed." The top students completed an average of 25.6 lessons of the 29 available while the bottom students completed an average of only 20.8.

The multiple regression employed to study the interaction of individual characteristics and instructional mode yielded results which suggest that indeed there are personality characteristics which differentially contribute to performance variance contingent upon membership in the CAI/Media or traditional group.

Before examining these closely, however, it is of interest to note that there are correlates with academic success which are common to both groups. Common positive relationships were found between performance and Florida 12th Grade Scores and OPI Religious Orientation (OPIRO). The results in Table 40 indicate these relationships as well as a common negative relationship between performance and the number of prior high school courses in science and mathematics (BKGD).

These findings suggest that success in the type of introductory physics which is represented in this course, regardless of the type of presentation, is related to the following attributes: persons who are generally skeptical and who are of liberal religious views and, in fact, have an overall liberal outlook, tend to be successful. This implies that those who are conservative and bound to traditional religious views are not intellectually free to be critical and objective in their approach to scientific thought and material. Further, these common relationships suggest that people who are more academically prepared on intellectually more capable (high Florida 12th Grade performance) have a high probability of performing well in physics. This is not surprising. It is reasonable to assume that bright students are more successful in college than the less bright. Finally, the last variable common to both regression equations is the number of background courses in science and math in high school. Surprisingly, however, this variable is negatively related to success for both groups. A possible explanation of this phenomenon is that students who had previously encountered many of the concepts of the physics course may have considered physics "easy" and therefore decided that it should not demand much study time. In contrast the students marginally prepared in math and science may have put in a great deal of study time to overcome their disadvantage at the outset of the course. If this hypothesis is correct, the payoff clearly accrued to the latter type of student.

The individual characteristics which differentially contribute to the performance variance contingent upon membership in the CAI/Media or traditional groups defines two, quite distinct, kinds of people. Persons who are successful after having instruction via the CAI/Media course can be characterized as follows: Since the masculinity-femininity scale of the OPI assesses some of the differences in attitudes between college men and women, the negative relationship here indicates that successful CAI/Media people tend to be stronger in esthetic and social inclinations and admit to greater sensitivity and emotionality. This is consistent with the negative correlation between the successful people in this group and score on the FACT questionnaire. FACT assesses the nature of inquiry as a correlate of academic success. The negative relationship here indicates that students succeeding in the CAI/Media course tended not to be like graduate students in the nature of their inquiry. The OPI Altruism (AM) scale indicates that further characteristics of this group are affiliation and trust. The negative correlation with the OPI Estheticism (ES) scale suggests that the successful CAI/Media students do not have diverse interests in artistic matters and activities. Finally, the CAI/Media group students had a positive test taking attitude (OPI Response Bias) and were people who had a concern about social injustices and "institutional wrongdoing."

In contrast, the characteristics of the students who were successful in the traditional lecture or control group were markedly different from those in the CAI/Media group. First, there was a strong positive relationship between course performance and the OPI MF scale. This, of course, is just the opposite of what was found with the CAI/Media group and is suggestive of successful people in the traditional lecture group being interested in scientific matters, somewhat less socially oriented, having interest in esthetics, and who admit to few personal inadequacies. The OPI Theoretical Orientation (TO) scale describes these people as interested in scientific activities and the scientific method of thinking. A negative correlation with the OPI Impulse Expression (IE) scale further indicates these people are not prone to engage in fantasies or to seek immediate gratification. In keeping with this same general characteristic of theoretical orientation, success in this group was found to be negatively related to practical outlook (OPI PO) and, therefore, describes individuals not interested in immediate utilitarian outcomes. Finally, the CSQ Liberalism (CSQ LI) and CSQ Peer Independence (PI) scale describe successful people in the traditional group as politically, economically, and socially liberal as well as autonomous with respect to their peers and unconcerned about the appearance of this behavior.

In summary, it has been found that there are individual characteristic correlates with academic success that are common to both the traditional and CAI/Media modes of instruction in P107 Physics. However, the more striking and interesting results show that persons who are slightly less mature in their academic style, who are more sensitive and esthetic, and who are not scientifically oriented have a higher probability of success if they take their physics instruction via the CAI/Media course. On the other hand, persons who are more autonomous, independent thinkers, who have scientific interests, and who have a mature, scientifically-oriented method of inquiry will have a greater chance of success if they take the traditional mode of physics instruction.

H. Conclusion

In conclusion, it is hoped that the findings of this section of the CAI physics research effort will lead to further investigation of individualized instruction in the area of media presentation augmented by enrichment discussion. It is also hoped that further investigation of interaction between individual characteristics and instructional mode might eventually lead to the improvement of the instructional process by directing students into differential course formats depending upon their personality attributes and learning styles.

IX

COST EFFECTIVENESS ANALYSIS

A. Introduction

The technique for performing cost effectiveness or cost benefit analyses remains very much in its infancy in the educational domain. Obviously, effectiveness can only be analyzed either by comparative standards, such as between two alternative instructional approaches, or by some absolute standards. If there are absolute standards for analysis of cost and learning effectiveness outcomes, this project has been unable to find them. Consequently, our analysis of effectiveness can best be understood within the context of utility theory; that is, the risks based on costs and potential learning losses can be derived in order to understand the effectiveness and benefits of two alternative instructional approaches as in the conventional lecture/demonstration course as opposed to the multi-media computer-based physics course.

Even utilizing the conceptual framework of utility theory, one still has the problems of precise operational definitions as well as functional relationships of the cost effectiveness variables. Some of these difficulties can be handled either through categorization techniques or in terms of economic models. For example, in the analysis, developmental costs for the multi-media computer-based physics course can be distinguished from the operating instructional costs. This categorization assumption is based upon the proposition that developmental costs can be amortized while operating instructional costs remain relatively fixed except for increases in salary or increases due to rescheduling of depreciation rates on capital equipment such as buildings and computers. As a corollary problem the value of savings in student time via more effective instruction that leads to faster learning rates presents serious assessment problems. This is primarily due to the fact that there is no reasonable measure by which to derive the value of the time of a collegiate student. Intuitively, one could use current cost of attendance plus projected duration in a career employment, but this is difficult in an undergraduate liberal education area. These problems as well as others seriously delimit the nature of the cost benefit analysis for the CAI course.

In terms of analyzing the effectiveness of the instructional process from the students' point of view, available techniques do not allow one to assess such factors as anxiety, potential risk in terms of alternative future careers, and overall personal development. The most reasonable and simplistic approach to academic learning is to consider performance on the final examination. If it is assumed that the final examination is a reasonable representation of the course objectives, one can calculate the mean proportion of these objectives that the group attained as opposed to what it potentially could obtain. Thus one must simplify the benefits considered in these analyses.

This leads directly to the problem of defining instructional effectiveness. The quantification of a concept such as instructional effectiveness is difficult at best. A simplistic functional relationship has been derived: namely, the risk to the educational institution is equal to the probability of a loss in effectiveness times the cost of the activity. While a host of other functional definitions could be offered for "effectiveness," this one seems most reasonable, based upon our investigations.

The first approach to effectiveness modeling consisted of utilizing the conceptions from economic analysis in underdeveloped countries; this economic model is referred to as Least Cost Analysis. These Least Cost Models look at alternative development and investment plans for an underdeveloped country and tend to stress the role of capital investment and depreciation rates. Profit and depreciation are usually predicated on weak ordered assumptions concerning the potential revenue and profit margin accruing to the country. Thus, alternative economic development plans are derived primarily on a consideration of capital investment and depreciation schedules. This is an analogous situation to technological approaches in education in that the amount of initial capital investment has clearly inhibited the rate of applications of technology as well as the serious concern over depreciation in the educational sphere. It is for these reasons plus the assumptions concerning learning effectiveness in education that have caused us to look at Least Cost Analysis Models as a conceptual framework.

In order to consider the cost benefits of the multi-media CAI physics course, a number of projections were performed which dealt with the possibility of increasing the size of the CAI system and looking at the effective operational cost. These types of analyses are delimited by the type of cost effectiveness statistic derived, namely a risk function, as well as the validity of the projections outlined. They are offered only as a preliminary start for providing more operational models of cost-benefit analyses.

In the remainder of this chapter the presentation is organized as follows:

1. The operational definitions of the cost and effectiveness statistics utilized in the analysis;

2. The total actual cost as categorized for the project;

3. The Least Cost Analysis Model;

4. Cost benefits analysis for future applications;

5. Conclusions

B. Definitions

Development costs - the funds expended for professional and implementational manpower, materials, and associated computer costs to develop the curriculum.

Instructional costs - the funds expended to provide instructional supervision and computer rental in order to offer the course to students.

Total costs - the full categorization of funds expended both by the sponsoring agent as well as the developmental group. In this case, Florida State University was the developing agency.

Sponsor costs - the funds provided by the federal agency, in this case, the U. S. Office of Education.

Student credit hours - the units of credit offered to a student upon successful completion of the course. In this case, the student credit hours were three in FSU quarter hour terms.

Hours of instruction - the contact time the student spends interacting with an instructor or a computer terminal.

Learning - performance of a student on the final examination. The examination should represent the course objectives.

Potential learning - the highest quantitative score possible on the final examination.

Actual learning - the number of problems on the examination successfully completed.

Risk - the potential loss involved in selecting an instructional alternative and is equal to the probability of the loss plus the cost of the loss event.

1. Total Cost. Table 41 presents the total cost for the computer-based physics project. These are broken down into two main divisions: development cost and instructional cost. Within the developmental division costs are further broken down into 1) professional manpower costs which represent a) the cost of professional staff to develop the curriculum, b) the cost of programming staff to encode the curriculum and develop the data analysis programs, c) the cost of graduate students to support experimental studies within the project and, d) the administrative costs. In turn, the equipment and material costs are categorized in terms of a) computing time and, b) media preparation. As to the instructional costs, these are again divided into a) manpower costs for proctoring, etc., and, b) computing and film rental relating to equipment and material costs. The costs are further separated into two accumulative time phases, that is, costs up to September, 1967, and all costs accumulated through the end of the project, January 1, 1969. These time phases reports allow for some indication of component costs over time.

Table 41

Costs of Developmental and Instructional Activities For the CAI Multi-Media Physics Project

Category	9/1/67		1/1/69	
	Expenditures	Man Yrs. of Effort	Expenditures	Man Yrs. of Effort
I. Developmental Costs				
A. Professional Manpower Costs				
1. Curriculum Preparation				
Physics Writers	$20,000	2.00	$30,000	3.00
Physics Faculty	20,000	1.00	25,000	1.25
Behavioral Scientists	14,000	1.00	42,000	3.00
Subtotal	54,000	4.00	97,000	7.25
2. Computer Programming & Coding				
CAI Coding	6,000	1.00	12,000	2.00
Data Management Programming	30,000	3.00	40,000	4.00
Data Analysis Programming	16,000	2.00	24,000	3.00
Subtotal	52,000	6.00	76,000	9.00
3. Experimental Studies Support				
Graduate Students	15,000	2.50	24,000	4.00
Subtotal	15,000	2.50	24,000	4.00
4. Administration				
Director	7,500	.50	11,250	.75
Secretaries	10,000	2.00	15,000	3.00
Subtotal	17,500	2.50	26,250	3.75
B. Computer and Materials Costs				
1. Computer Time				
CAI Coding	6,000		9,000	
Systems Programming	20,000		25,000	
Data Analysis	3,000		9,000	
Subtotal	29,000		43,000	

Table 41 continued.

2. Media Preparation				
Films and Graphics	4,000		6,000	
Audio	1,500		2,000	
Subtotal	5,500		8,000	
Total Developmental Costs	$173,000		$274,250	
II. Instructional Operational Costs				
A. Manpower				
Proctor	2,500	.90	3,500	1.20
Computer Operators and Technicians	3,000	.50	4,500	.75
Subtotals	5,500	1.40	8,000	
B. Computer and Film Costs				
Computer	3,000		6,000	
Film Rental	500		750	
Audio	250		500	
Subtotal	3,750		7,250	
Total Instructional Costs	9,250		15,250	
TOTAL PROJECT COSTS	$182,250		$289,500	

To better reflect the breakdown of the category expenditures, Table 42 presents percentage of each sub-category expenditure within the total costs. It is worth noting that the developmental cost consumed 95 percent of the budget. Without a doubt, the greatest cost was for the development of an appropriate data analysis and management system to effect the required revisions of the automated physics course. While this is a one-time cost, this programming system was not provided by the manufacturer and was absolutely essential to the successful completion of this project. All future CAI systems will require such data analysis and management sub-systems and costs comparable to this percentage will be involved whenever a new computing system is acquired and utilized.

One can contrast the total costs of the project to the cost paid for by the sponsoring agent, that is, the U. S. Office of Education. Table 43 presents a similar breakdown of the expended $240,000 paid by the U. S. Office of Education. Again, it is worth noting that categories like university overhead absorbed a large proportion of the money and were not available for the project research and development work. In this type of exploratory research it is very worthwhile considering the total cost in that an institution has to have an informal mechanism by which to cover the difference between sponsored cost and actual cost. Universities' research groups have to have informal mechanisms such as recruitment of free, dedicated professional time as well as allocation of inexpensive graduate student time to projects of this nature in order to match the total costs with the requirements of the project. One would hope that in the future a better recognition of the total cost can be portrayed in research projects of this nature.

2. Least Cost Analysis Model. In utilizing the concepts from the Least Cost Analysis Model, one tends to stress the current and projected costs as well as depreciation of capital investment in determining the relative merits of two or more alternative investments. For our case, this represents a comparative analysis between the multi-media computer-based physics course as opposed to the Florida State University lecture course. The model suggests that because profits, or in the educational case, learning effectiveness, are open to changes in market price fluctuations, one tends to select that alternative with both a dropping cost and a dropping depreciation rate. In essence, the nature and structure of the cost depreciation schedules becomes the deciding factor, i.e., one looks for a depreciation schedule that is rapidly approaching zero in order to look for a quick return on capital investment. In the educational case, one looks for low depreciation which is approaching zero so that new educational alternatives can be pursued if desired.

Utilizing the information from Table 42, an analysis was performed for the least cost model on the basis of current costs during the project as well as cost projections for 1975. This six-year time span provides a minimal look at the tendency for cost and depreciation to be reduced. In terms of the CAI course, the operating instructional cost as presented in Table 44, was $1.78 per instructional hour. This was derived by the fact that the total operating instructional cost was

Table 42

Percentage Costs of Developmental and Instructional Activities For the CAI Multi-Media Physics Project

	Percent of Total Cost	
I. Developmental Costs	8/1/69	1/1/69
A. Professional Manpower Cost		
Curriculum Preparation	30	34
Computer Programming & Coding	28	26
Experimental Studies Support	8	8
Administration	10	9
B. Computer and Materials Cost		
Computer Time	16	15
Media Preparation	3	3
Total Developmental Costs	95%	95%
II. Instructional Operational Costs		
A. Manpower	3	3
B. Computer and Film Costs	2	2
TOTAL PROJECT COST	100%	100%

Table 43

Cost Analysis for a Collegiate CAI Physics
Curriculum Development Project

Category	Item Cost	Totals
Curriculum Preparation		
Behavioral Scientists	12K	
Physics Writers	12K	
Physicists	6K	30K
CAI Coding		
CAI Coding Personnel	12K	
Computer Time	10K	22K
Film and Graphics Production		
Art work and service cost	6K	6K
Computer Programming		
Data Management Programming	54K	
Data Analyses Programming	15K	69K
CAI Instructional Cost		
CAI Computer Costs	15K	
Proctors	3K	18K
Experimentation		
Graduate Students	24K	24K
Office and Clerical	10K	10K
University Overhead	60K	60K
TOTALS	239K	239K

$15,250, and 8,552 hours of instruction were provided to FSU students (the 8552 hours are a sum for both the autonomous CAI instruction plus the CAI problem exercise instruction). In turn, the potential cost for the CAI physics in 1975 is projected at $.45 per hour. This cost is derived by dividing the $1.78 by 4, i.e., the projected cost for the CAI computer equipment and media equipment six years hence. This is not an overly optimistic estimate in that the reports from University of Illinois indicated that the hourly operating cost will be below $.30 per hour for their projected system to be delivered in 1972, as well as the fact that an existing Digital Equipment Corporation PDP/8-I computer system can be operated at less than $.30 per hour of instruction, given that one is willing to present the curriculum via a teletype instructional terminal. The PDP/8-I CAI system has only recently become available and would require additional computer systems work in the areas of constructed response analyses, response recording, and data analysis-management programs. Still the current price of a 32-terminal time-sharing disk-oriented CAI system that can be obtained from either the Digital Equipment Corporation, Hewlett-Packard or Systems Engineering Laboratories is in the range of $100,000 to $150,000. If full utilization for instruction is performed, the cost per hour is less than $.30.

Table 44 also indicates that the lecture cost for presenting the physics course during the latest term in 1968 was $.51 per instructional hour for each student. This is predicated on the fact that 25% of the professor's salary ($5,000) was allocated to this course, plus the cost of four graduate students, plus 20% of the wages of a technician who prepared the class demonstrations. The projection of $.84 for 1975 for the lecture course is based on taking an estimated salary increase of 6% a year during this time duration. Thus, one can see that the operating costs for CAI are dropping rapidly, whereas one can anticipate an ever-increasing instructional operating cost for conventional instruction which is directly tied to the inflationary effects on personnel salary.

More important to the Least Cost Analysis Model is that the depreciation for the CAI physics system and material is most encouraging. In terms of analysis, it was assumed that the physics course developed under this project would be usable for a five-year duration. One could, in fact, claim a much longer useful life and reduce the cost, but the five-year estimate seemed to be a more conservative estimate. In terms of calculations, the development costs were $174,250. This was determined by summing the categories of professional manpower, administration, and computer material cost, i.e., all the developmental costs minus the categories of computer programming and the experimental studies. The development cost for the final 33 hours of CAI material was $5,280 per hour. Given that 72 hours were in fact developed during the revision process, the cost for development of any given instructional CAI hour was $2,420. The difference of $2,860 gives an indirect estimate of the cost of revision when developing a CAI course.

Table 44

Least Cost Analysis for CAI Physics in Contrast with a Lecture Physics Cost

	CAI PHYSICS		LECTURE PHYSICS	
	1969	1975	1969	1975
Operating Instructional costs per hr.	$1.78	$ .45	$ .51	$ .84
Depreciation Costs per instructional hour	4.07	.61	.68	.75
Total Costs per instructional hour	$5.85	$1.06	$1.35	$1.59

When these developmental costs are projected over five years in terms of their depreciation, the costs for instruction during 1969 was $4.07, i.e., 1/5 of $174,205 divided by 8,552 hours of instruction. Given that one would provide instruction on a more massive basis, i.e., providing physics instruction on a comparable computing system that has 64 terminals, one finds that the depreciation costs are $1.06 for 1975. On the other hand, the depreciation costs for the lecture course was $.68 for the fall quarter of 1968. This figure is derived from the cost of a $400,000 facility amortized over 20 years plus the various demonstration and media equipment. Given an increase in the cost of equipment replacement, it is anticipated that the depreciation costs will rise to $.75 by 1975 for the lecture course. Thus again one notices rising depreciation costs for conventional instruction and falling depreciation costs for CAI.

In summary, it is clear that the current status of a multi-media CAI physics course is slightly less than five times as costly as a conventional lecture class for the academic year 1968-69. On the other hand, it is anticipated that within six years, the cost of a CAI physics operation will have dropped by an order of five, whereas the conventional lecture course will continue to rise While there are many assumptions involved in making this least cost analysis, it is clear that CAI courses are a much more appropriate investment alternative for an educational institution. This is based on the fact that they have projected falling costs as well as depreciation. Consequently, one can anticipate an accelerating increase in the use of this form of technology for instruction within the next half decade.

3. Cost Benefit. In attempting to provide a cost benefit analysis for the outcomes of the project, two major problem areas were identified. The first one was the inability to attach a value to higher learning performance levels: i.e., given that the CAI students performed consistently better than the lecture course students, what is the value of this better performance level? Secondly, the CAI students saved time in the completion of the course. It may be assumed that a student's time is valuable. Consequently, in our approach to cost benefit analysis, we attempted to take both of these factors into account.

One can use utility theory and the concept of risk as one possible method for deriving cost benefits. Risk is defined as equal to the probability of a given loss outcome times its cost. In looking at the two instructional alternatives, one attempts to minimize risk, given an assumption of equal profit. In defining the probability of the outcome, the concept of potential minus actual test performance was utilized, i.e., the difference between actual learning and potential learning was considered as an estimate of the probability of an undesirable outcome. For the CAI physics final test performance in the spring of 1968, the potential score was 40 and the mean was 23.65. Calculating the difference and converting to a proportion for loss yields a probability estimate of .409 for the CAI physics group. The lecture group had a mean of 21.87 and a loss probability estimate of .453. In turn, cost was defined by cost per instructional hour minus the savings in time as determined by the value of a student's hour.

The value of a student's hour was calculated as follows: a student's cost at Florida State University is approximately $1,500 per quarter for tuition, living expenses, and normal academic recreation. Given that the physics course represents 1/5 of the normal academic load, and that there was a 15% time savings, it can be calculated that the cost savings was approximately $1.50 an hour for each student's instructional hour. Consequently, the CAI version of risk equals the probability of loss performance (.409) times the cost quantity of $5.85 per hour minus the savings of student time, $1.50. This yields a risk factor of 1.78. In turn, the lecture course had a loss performance proportion of .453 and a cost of $1.35 with no time savings. This yielded a risk factor of .61.

The risk of the lecture course during the duration of the project was less than that of the CAI course. One should note that in terms of risk, the CAI course is slightly less than three times as great as the lecture course. Thus, by using utility theory, one can see that the risk at the present time of pursuing an autonomous CAI course is not nearly as undesirable as reflected by the least cost analyses. This difference between least cost, which was five times as great for CAI, and risk analyses may be interpreted as the effectiveness of the approach, i.e., the effectiveness of the CAI approach seems to cut your cost differential by nearly two orders of magnitude when considering effectiveness in time savings and performance levels of the coutcome. If a favorable trend for CAI should continue, it again argues that computer-based courses will become exceedingly popular during this coming decade.

C. Conclusions

1. The developmental cost of this CAI R-and-D project absorb approximately 95 percent of expenditures in comparison with instructional costs. A significant percentage (26%) are required for computer systems programs not furnished by the manufacturer. It is recommended that computer manufacturers extend this software package provided with a CAI system to include a data analysis and management system.

2. It was found that a typical hour of CAI learning materials cost $2,420 to create and cost $5,280 after extensive field testing and revision. The revision process cost for an hour of CAI materials was estimated at $2,860.

3. Least cost analyses indicated that CAI has both decreasing instructional operating and depreciation costs. It was estimated that within six years CAI will be more economical than conventional instruction although it is currently less advantageous.

4. Cost benefit analyses indicated that the improved learning effectiveness of CAI allows for a two order of magnitude decrease in loss risk as compared with cost comparisons.

X

CONCLUSIONS AND SUMMARY

Curriculum development techniques and procedures were both explored and discovered during the implementation of the multi-media computer-based collegiate physics project. The primary outcome of this implementation process was a formal conceptual model referred to as the systems approach to CAI curriculum development. The essential components of the systems approach are: 1) problem identification, 2) task analysis, 3) student entry behaviors, 4) behavioral objectives, 5) instructional strategy, 6) media assignment, 7) field test, 8) revision cycle, and 9) management techniques. As a consequence of the utilization of the systems model in the development of the physics course, ten significant professional roles in multi-media CAI curriculum development have been identified. In addition, computer data analysis and management systems required for the support of the curriculum revision cycles have been determined.

Briefly, the following seven factors seem critically important in determining the rate of development and success of a computer-based curriculum project:

1. The use of the systems approach and the clarity of the behavioral objectives derived for the CAI curriculum will determine the rate with which a project will be developed.

2. The variety and frequency with which varying response modalities such as speech, light pen, keyboard, etc., are required in a course can affect the rate at which a CAI curriculum can be implemented.

3. Terminal criterion performance levels for the CAI course will determine both the instructional sequence as well as the complexity of the instructional strategy. In turn, the complexity of the instructional strategy will determine the developmental rate of the project.

4. The variety of multi-media utilized in the CAI course will determine the implementation rate and the logistic ease of the instructional process.

5. The number of revision cycles required to develop an "optimal version" of a CAI course remains an unanswered question. However, the use of CAI problem sets to determine baseline performance and video recording of excellent instruction in a conventional setting allows for a limited number of revision cycles.

6. The degree of sophistication of the CAI operating system is highly critical in determining the rate of development. The availability of an efficient coding language with macro techniques plus an operative data analysis and management system is highly essential for a favorable rate of development.

7. The number of experimental versions of the CAI course will determine the rate with which the project successfully reaches closure. However, investigation of experimental issues is necessary for the full evaluation and validation of the curriculum.

8. Since it is recognized that CAI curriculum development is a highly complex process, the use of multiple role differentiation techniques and specific functional assignments for staff members leads to more effective and efficient rates of development.

A. Description of Course

The Florida State University CAI physics course utilized a wide variety of media approaches rather than restricting the informational presentation to the terminal devices (cathode-ray tube, light pen, and keyboard) of the 1500 CAI system. The additional media were: textbooks, audio lectures, and notes, concept film loops, and PSSC films.

The CAI physics course followed the same general outline as the companion course taught by lecture. The CAI students were allowed to schedule their own time at the CAI Center. At the Center, their progress was directed by a computer terminal. Problems and instructions to the student were displayed on the cathode-ray tube (CRT). The student could indicate his response to the computer by typing his answer on the keyboard or by touching a light pen to the appropriate location on the CRT.

A typical lesson in the course began with the student reporting to the computer terminal and taking a short quiz based upon a reading assignment. If the student did not pass the quiz, he was instructed to reread the material and return to take the quiz again. If he was successful, the student was directed to listen to a short audio lecture on the major topic of the lesson. A special cartridge system provided the audio lecture for the student at his terminal. The student was also provided with an outline which included helpful drawings relevant to the lecture. After completing the lecture, the student would be quizzed via the terminal on the audio presentation. The student would then be directed to a single concept film loop or a PSSC film. The single concept film loop presented demonstrations of some of the major concepts included in the lesson. Outlines were also available for the film loops. If the student was directed to view a PSSC film, he would notify a proctor who in turn would operate the film projector. The student then returned to his terminal to take a short quiz on the film. Based upon the lesson content, the student might be directed to other presentations on various media At the completion of the entire sequence of instruction, the student was given certain review problems via the CRT, and then was given his next textbook assignment.

Special midterm and final examination reviews were available on another computer system, the IBM 1440. This system consisted of only a typewriter terminal and therefore the student-computer dialogue was typed. This system had the advantage that it provided the student with a printout of his review. Students from the lecture courses also were allowed to use this computer review. Two sets of paper and pencil practice homework problems were also assigned, one before each examination.

B. CAI Physics Problem Exercises

When considering the most efficient method of developing an autonomous computer-based course which was to be based upon the structure of an ongoing instructional program, the decision was made to first develop those parts of the physics course which could contribute to the understanding of entry performance levels of the student and to the development of appropriate behavioral objectives. The physics problem exercise course involved the development and field evaluation of physics review material, problem exercises, and prototype exam questions to complement the existing lecture series. The review sections represented a parsimonious statement of the central propositions found within the four major content areas of the introductory physics course. In the conventional course, the students are required to identify important definitions and relational statements. The problem sections of the CAI physics problem exercise course were programmed in a form analogous to the problems given as homework assignments. The sample test questions were essentially parallel test items to those found in the hourly and final examinations in the course.

The basic strategy in developing these CAI physics problem exercises was to establish a baseline by which it could be determined whether future curricular developments were really improvements. Consequently, these review and problem sessions provided naturalistic, baseline data by which to judge whether the total course, which includes the complete presentations of all the topics, is equivalent or superior to conventional instruction.

In addition to providing baseline data, the field study of the CAI problem exercises conducted in the fall term, 1966, and the winter term, 1967, established the usefulness of the CAI instructional approach as evidenced by the steadily increasing voluntary participation. Moreover, it provided a set of problem exercises that were revised for inclusion in the full autonomous course, and it helped to identify those particular learning problems that the full course would have to face.

This experience with the FSU students indicated the feasibility of a computer-based course. The merits of approximating a course via this strategy is recommended to other CAI R-and-D projects. Moreover, the positive outcomes suggest the desirability of having this kind of CAI application available for any number of collegiate courses.

C. Field Studies

The fall 1967 field study was implemented with 23 students in the autonomous CAI group, a matched group of students taking the conventional physics course and a matched group receiving the conventional lectures plus review questions on the 1440 system.

The learning outcomes as reflected in the final grade assignments for the three groups indicated that the autonomous CAI group was statistically superior to the other two groups, but the differences between the partial CAI and the conventional students were not significant. The high proportion of A grades found in the autonomous CAI group represents one of the few instances in which the upper half of a score distribution shifted under CAI.

The mean length of time required by the CAI students for completion of the course was 10.9 weeks in the 11 week term. However, the mean time required to complete the 29 lessons for the autonomous CAI group was 23.8 hours of instruction. This represents a 17% savings in instructional time.

The CAI lesson material was categorized into three types of instruction (assessment of textbook reading, assessment of film presentations and conceptual assessment via CAI problem presentations). Comparison of performance on various topics in the lesson materials with the prior baseline data previously collected showed that the performance on the textbook assessment and the conceptual problem exercises were markedly constant. However, the conventional course performance was marked by a gradual decrease in achievement as the conceptual complexity of the physics topics is judged to be increasing. In addition, the CAI conceptual problem scores yielded a significantly higher multiple correlation with the examination scores.

In considering the empirical outcomes from this first field test, the substantial, multiple-correlation relationship between the CAI conceptual exercise material and the examination scores that lead to the grade outcomes was most encouraging. A class of linear models is currently under investigation that, hopefully, will provide each student with realistic probability statements about course mastery. If the values become too low, additional practice on a concept will undoubtedly be prescribed. Otherwise, the student will be allowed to self-define his level of course proficiency. The element of student self-commitment may represent a more viable pathway to optimizing the terminal outcomes for an individualized course of instruction.

1. Spring Term, 1968. During the winter quarter, 1968, the entire course was reviewed in light of the student performance data, student attitudes about the course, and the logistical problems which had been encountered during the fall 1967 field test of CAI physics. In addition, a battery of cognitive and affective tests were selected to be administered in an attempt to understand the relationship of prior knowledge and entering aptitudes to success in the CAI course.

The performance of the CAI autonomous group (37 subjects) was compared to the performance of the subjects attending only the conventional lectures and to that of subjects attending both the conventional lectures and a four-hour examination review on the 1440 CAI system. Although there was no significant difference in the test performance of the CAI group in comparison to either of the other groups, the CAI did show a learning time savings of approximately 12 percent.

Analysis of student performance on within-course measures indicated stability across and within lessons with the exception of the film quizzes. An anxiety measure was not generally correlated with within-course performance. The multiple R for predicting final grade in course, using the 10 best background and within-course measures, was .86.

The post-course interview data reflected a generally positive attitude on the part of the students. The course organization was highly satisfactory and none of the course concepts were judged to be unduely difficult. About half of the students preferred the 1500 CRT system, 27 percent preferred the 1440 typewriter system, and 23 percent had no preference.

2. Fall, 1968. Given the overall success of the CAI physics course as evidenced by the fall 1967 and spring 1968 field studies, this study was concerned with two basic questions: 1) Are particular individuals better suited to a specific media due to their particular interests or personality characteristics? and, 2) What is the effect of augmenting a basic media presentation with student enriched discussions?

Twenty-two student volunteers who participated in a year-long Freshman Learning Experience (FLEX) were used in the study. The FLEX program replaced the standard class meetings with less formal and more flexible arrangement of student-instructor interaction.

The CAI media course used in this study was not the complete autonomous course heretofore described. This project utilized a modified version of the CAI course from which all reading assignments and some film and CAI materials were deleted in order to provide about two-thirds of the normal course load. In this context, the instructional aim of the CAI media program was to enable these students to acquire the basic physics knowledge from the CAI media course in no more than two-thirds of the time that they had available for physics, i.e., using no more than two of the three contact hours per week which were assigned. A classroom meeting used the remaining hour for presentation of additional enrichment material of value to these non-science majors. Therefore, the physics instruction which the FLEX students received was in two major parts:

(1) Students received the 29 lessons available on the 1500 CAI/media system which constituted the "basic objectives" of the P107 course.

(2) In addition, students received instruction for one hour per week with a physics professor in a recitation session.

In this way, the project provided a means of investigating both the possible student by instructional treatment interaction as well as the CAI/media augmented by recitation sessions.

Comparison of the performance of the CAI FLEX group with the performance of 22 subjects taking the conventional physics course showed no significant differences between the groups on final grade achievement or performance on the traditional examination. This outcome is based upon a comparison of a control group with those students in the FLEX group who had finished all 29 lessons of the CAI/media course.

It was found that there were individual characteristics which correlated with academic success that were common to both the traditional and CAI/media modes of instruction in Introductory Physics. However, the more striking results suggest that generally speaking persons who are slightly less mature in their academic style, who are more sensitive and esthetic, and who are not scientifically oriented, have a higher probability of success if they take their physics instruction via the CAI/media course. On the other hand, persons who are somewhat autonomous, independent thinkers, who have scientific interests and have a mature scientifically-oriented method of inquiry will have a greater chance of success if they take the traditional mode of physics instruction.

In terms of cost-benefit analyses of the CAI physics course, the developmental cost of this CAI R-and-D project absorb approximately 95% of expenditures in comparison with instructional costs. A significant percentage (26%) are required for computer systems programs not furnished by the manufacturer. It is recommended that computer manufacturers extend this software package provided with a CAI system to include a data analysis and management system. As to instructional costs for preparation, it was found that a typical hour of CAI learning materials cost $2,420 to create and cost $5,280 after extensive field testing and revision. The revision process cost for an hour of CAI materials was estimated at $2,860.

Least cost analyses indicated that CAI has both decreasing instructional operating and depreciation cost. It was estimated that within six years CAI will be more economical than conventional instruction although it is currently less advantageous. Cost benefit analyses indicated that the improved learning effectiveness of CAI allows for a two order of magnitude decrease in loss risk as compared with cost comparisons.

REFERENCES

Allen, W. H. Audiovisual communication research. In C.W. Harris (Ed.), Encyclopedia of educational research (3rd ed.) New York: MacMillan, 1960, 115-137.

Atkinson, Richard C. The computer is a tutor. Psychology Today, 1968, 1, (8), 36-39; 57-59.

Baker, J.D. Cokis computer based instruction system. Newsletter, Greater Boston Chapter of the Society for Programmed Instruction. 1965, 1, (04).

Barr, A.S., et al. Radio in the classroom. University of Wisconsin, 1942.

Bolte, J.R. Predicting performance in high school physics. Journal of Research in Science Teaching, 1966, 4, 74-78.

Briggs, L. J., & Argell, D. Programmed instruction in science and mathematics. Review of educational research, 1964, 34, (3), 354-373.

Briggs, L.J. Learner variables and educational media. Review of educational research, Vol. XXXVIII, No. 2, April, 1968.

Briggs, L.J. Personal communication with the author. October, 1968 (a).

Bush, W. J., Gregg, O.K., Smith, E.A., McBride, C.B. Some interactions between individual differences and modes of instruction. Aerospace medical research laboratories, Wright-Patterson A.F.B. Final Report, 1965.

Campeau, P. L. Selected review of literature on audiovisual media of instruction. In Leslie J. Briggs', et al., Instructional media: A procedure for the design of multi-media instruction, a critical review of research, and suggestions for future research. Monograph No. 2, Pittsburg, Pa.: American Institutes for Research, 1967. Chapter 5, pp. 99-142.

Campeau, P. L. Test anxiety and feedback in programmed instruction Journal of Educational Psychology, 1968, 59, 159-163.

Champa, V.A. Television: its effectiveness in ninth-grade science teaching. AV Communication Review, 1958, 6, (3), 200-203.

Cobbs, C.T. Use of natural science sound films in primary grades. Educational Screen, 1941, 20, (2), 57-58.

Cook, D.C., & Nemzek, C.L. The effectiveness of teaching by radio. *Journal of Educational Research*, 1939, *33*, (2), 105-109. In C.W. Harris (Ed.), *Encyclopedia of Educational Research* (3rd ed.). New York: MacMillan, 1960, 115-137.

Cooper, J.C., Jr., & Gaeth, J.H. Interactions of modality with age and with meaningfulness in verbal learning. *Journal of Educational Psychology*, 1967, *58*, 41-44.

Doty, B.A., & Doty, L.A. Programmed instructional effectiveness in relation to certain student characteristics. *Journal of Educational Psychology*, 1964, *55*, 334-38.

Dunlap, J.L. Predicting performance in high school physics. *Physics Teacher*, 1964, *4*, (7), 303.

Evans, J.L., Glaser, R., & Homme, L.E. An investigation of variation in the properties of verbal learning sequences of the "teaching machine" type. In A.A. Lumsdaine & R. Glaser (eds.), *Teaching machines and programmed learning*. Washington, D.C.: National Education Association, 1960. Pp. 446-551.

Finger, J.A., Dillon, Corbin F. Performance in introductory college physics and previous instruction in physics. *Journal of Research in Science Teaching*, 1965.

Franceschi, D., & Hansen, D. An experimental study to determine the effectiveness of supplementary instructional television with computer-assisted instruction. In D. Hansen & W. Dick, *Semiannual progress report, January 1, 1967 through June 30, 1967*. CAI Center, Institute of Human Learning, Florida State University, Tallahassee, Florida. Pp. 82-92.

Greenhill, L.P. A review of some trends in research on instructional films and instructional television. In D. W. MacLennan and J.C. Reid (Eds.), *Abstracts of research on instructional television and film: an annotated bibliography*. Stanford University, 1964, Pp. 1-32. (Mimeographed)

Gropper, G.L., & Kress, G.C., Jr. Individualizing instruction through pacing procedures. *AV communication review*, 1965, *13*, pp. 165-82.

Hansen, D. N., & Dick, W. *Semiannual progress report: January 1, 1967 through June 30, 1967*. CAI Center, Institute of Human Learning, Florida State University, Tallahassee, Florida. 247 pp.

Hartley, J. Social factors in programmed instruction--a review. Reprint from *Programmed Learning*, Sweet and Maxwell, LTD. Great Britain, 1966. Cited in A.E. Hickey, *Computer-Assisted Instruction--a survey of the literature*. Newburyport, Massachusetts. Entelek, Inc., 1968.

Hassan, M.A. A study of the relationship between achievement in a general college physics course and several selected factors. Unpublished M.S. thesis, Department of Mathematics and Science Education, North Carolina State University at Raleigh, 1966.

Hellerstein, E., Mast, E., & Stolurow, L. CAI - Socratic dialogue and laboratory simulation in pathology. Technical Report, October, 1967. Harvard Computing Center.

Hickey, A.E. (Ed.) Computer-Assisted Instruction: A survey of the literature. (3rd ed.) Newburyport, Mass. Entelek, Inc., 1968.

Hipscher, W.L. Study of high school physics achievement. Science Teacher, 1961, 28, 36-37.

Huffman, S. A. A comparative analysis of four instructional methods in eighth-grade science. Unpublished doctoral dissertation, University of Virginia, 1958. Cited in D.W. MacLennan and J.C. Reid (Eds.), Abstracts of research on instructional television and film: an annotated bibliography. Stanford University, 1964. (Mimeographed).

James, N.E. Personal preference for method as a factor in learning. Journal of Educational Psychology, 1962, 53, 43-47.

Kight, H.R., & Sarrenrath, J.M. Relationship of achievement motivation and test anxiety to performance in programmed instruction. Journal of Educational Psychology, 1966, 14, 185-191.

Kropp, R.P., Nelson, W.H., & King, F.J. Identification and definition of subject matter content variables related to human aptitudes. Final Report, U.S. Office of Education, #OE-5-10-297., January, 1967.

Kruglak, H. Evaluation of high school physics courses by college students. American Journal of Physics, 1959, 27, 630-634.

Lublin, S.C. Reinforcement schedules, scholastic aptitude, autonomy need, and achievement in a programmed course. Journal of Educational Psychology, 1965, 56, 295-302.

Lumsdaine, A.A., & May, M.A. Mass communication and educational media. Annual Review of Psychology, 1965, 16, 475-534.

MacLennan, D.W., & Reid, J.C. (Eds.), Abstracts of research on instructional television and film: an annotated bibliography. Stanford University, 1964. (Mimeographed).

Mandler, G., & Sarason, S.B. A study of anxiety and learning. Journal of Abnormal and Social Psychology, 1952, 47, 166-173.

McElroy, C.W. An experimental study to determine the effect of motion pictures in reinforcing instruction for the improvement of speaking techniques of students in beginning public speaking classes. Unpublished doctoral dissertation, University of Virginia, 1958. Cited in D.W. MacLennan and J.C. Reid (Eds.), Abstracts of research on instructional television and film: an annotated bibliography. Stanford Univ., 1964. (Mimeographed).

Melaragno, R. A study of two methods for adapting self-instructional materials to individual differences. Santa Monica, California: Systems Development Corporation Final Report 6210-M517, June, 1966.

Miles, J.R. Radio and elementary science teaching. Journal of Applied Psychology, 1940, 24, 714-720.

Moldstad, J. Summary of AV research. Audiovisual Instruction, 1964, 9, 492-497.

Murphy, F.E. The relative effectiveness of filmed introductions to a general science motion picture. Unpublished doctoral dissertation, Boston University, 1961. Cited in D. W. MacLennan and J.C. Reid (Eds.), Abstracts of research on instructional television and film: an annotated bibliography. Stanford University, 1964. (Mimeographed).

Nelson, C.M. Effectiveness of sound motion pictures in teaching a unit on sulphur in high school chemistry. School Science and Mathematics, 1952, 52, (453), 8-10.

O'Reilly, R.P., & Ripple, R.E. The contribution of anxiety, creativity, and intelligence to achievement with programmed instruction. Paper presented at the American Education Research Association, New York, 1967.

Popham, W. J., & Sadnavitch, J. M. The effectiveness of filmed science courses in public secondary schools. Department of Education and Psychology, Kansas State College of Pittsburg, August, 1960. Abstracted in AV Communication Review, 1961, 9, (4), A28-A29.

Popham, W. J. Tape recorded lectures in the college classroom. AV Communication Review, 1961, 9, 109-118.

Popham, W. J. Tape recorded lectures in the college classroom - II. AV Communication Review, 1962, 10, 94-101.

Porter, D. A. Some effects of year-long machine instruction, In E. H. Galanter (Ed.), Automatic teaching: The state of the art. New York: Wiley, 1959, pp. 85-90.

Proctor, W. L. A comparison of the effects of computer-assisted instruction and lecture discussion methods of presentation in a general curriculum class. In D. Hansen, & W. Dick, Semiannual progress report: July 1, 1967 through December 31, 1967. CAI Center, Institute of Human Learning. Florida State University, Tallahassee, Florida, pp. 23-24.

Renner, J. W., Whitaker, R. J., & Bautisita, L. B. Is high school physics a waste for college preparation? American Journal of Physics, 1965, 33, 618-624.

Ripple, R.E. Comparison of the effectiveness of a programmed text with three other methods of presentation. Psychological Reports, 1963, 12, 226-237.

Rodgers, T.S. CAI and the Teaching of Economics. Cited in A. A. Lumsdaine (Ed.) New developments in the teaching of economics. Englewood Cliffs, N. J., Prentice-Hall, 1967.

Roe, A. Automated teaching methods using linear programs. Journal of Applied Psychology, 1962, 46 , (3), 198-201.

Sadnavitch, J. M., & Popham, W. J. Retention value of filmed science courses. Pittsburg, Kansas: Department of Education and Psychology, Kansas State College of Pittsburg, August, 1961. Abstracted in AV Communication Review, 1962, 10, (1), A80-A81.

Sarason, I.G. Empirical findings and theoretical problems in the use of anxiety scales. Psychological Bulletin, 1960, 57, 403-415.

Sarason, S. B., Davidson, K. S., Lighthall, F. F., Wait, R. R., & Ruebush, B. K. Anxiety in elementary school children. New York: Wiley, 1960.

Schramm, W. S., & Oberholtzer, K. E. (Principal Investigators). The context of instructional television: Summary report of research findings, the Denver-Stanford Project. Denver, Colorado, and Stanford, California: Denver Public Schools and Stanford University, June, 1964.

Shuford, E. H., Jr. Cybernetic testing. Presented at symposium, Current Trends in Computer-Based Instructional Systems, held at National Society for Programmed Instruction Convention, 1965.

Shuford, A., & Massengill, E. H. Admissible probability measurements procedure. Psychometricka, June, 1966, 31, No. 2.

Smith, W.I., & Moore, J. W. (Eds.) Programmed learning: Theory and research. Princeton, New Jersey: D. Van Nostrand Company, Inc., 1962, 240 pages.

Snow, R.E., Tiffin, J., & Seibert, W. F. Individual Differences and instructional film effects. Journal of Educational Psychology, 56: 315-26, December, 1965.

Snow, R. Aptitude-instructional treatment interactions: Selected findings and hypotheses. Paper presented at the annual meeting of American Educational Research Association, Los Angeles, February, 1969.

Snyder, W. R. The role of CAI in the formative evaluation of the intermediate science curriculum study. In D. Hansen, et al. Semiannual Progress Report: July 1, 1967 through December 31, 1967. CAI Center, Institute of Human Learning, Florida State University, Tallahassee, Florida. Pp. 195-210.

Spielberger, C.D. The effects of anxiety on complex learning and academic achievement. In C.D. Spielberger (Ed.), Anxiety and behavior. New York: Academic Press, 1966b, pp. 361-398.

Strong, P.N., Jr. Research accomplishments and needs in programmed instruction. In G.D. Ofiesh, & W. C. Meierhenry (Eds.), Trends in programmed instruction. Washington, D.C.: Dept. of Audio-visual Instruction, National Education Association and National Society for Programmed Instruction, 1964, pp. 224-230.

Stuit, D. C. An experiment in teaching: Iowa closed-circuit television teaching experiment summary report. Iowa State: State University of Iowa, August, 1956. (Mimeographed) Cited in D. W MacLennan & J. C. Reid (Eds.), Abstracts of research on instructional television and film: An annotated bibliography. Stanford University, California, 1968.

Suppes, P. Modern learning theory and elementary school curriculum. American Educational Research Journal, 1964, 1, 79-93.

Suppes, P. Progress report: Stanford program in computer-assisted instruction for the period April 1, 1968 to June 30, 1968, Institute for mathematical studies in the social sciences, Stanford University, Stanford, California, 1968.

Tendam, D. J. Preparation and evaluation in use of a series of brief films of selected demonstrations from the introductory college physics course. Final Report. (Lafayette) Purdue Research Foundation, August 31, 1961. (Offset) Cited in D. W. MacLennan & J. C. Reid (Eds.), Abstracts of research on instructional television and film: An annotated bibliography. Stanford University, 1964. (Mimeographed)

VanderMeer, A. W. Relative effectiveness of instruction by--films exclusively, films plus study guides, and standard lecture methods. Pennsylvania State University Instructional Film Research Program. Port Washington, Long Island, New York: Special Devices Center, July, 1950.

Wendt, P. R., & Butts, G. K. Audiovisual materials. Review of Educational Research, 1962, 32, 141-155.

Wiles, M. K. The evaluation of school news broadcasts. Unpublished doctoral dissertation, Ohio State University, 1940.

Woodruff, A. B., Faltz, C., & Wagner, D. Effects of learner characteristics on programmed learning performance. Psychology in the Schools, 1966, 3, 72-77.

Woodward, C. S. Factors in a student's cumulative scholastic record which predict achievement in a first course in college physics. Stillwater, Oklahoma: Oklahoma State University, 1963. Dissertation Abstracts 24: 337, pp. 96.